THE INFLUENCE OF GRAZING INTENSITY ON THE PERFORMANCE OF TROPICAL GRASSES

By

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"How the beasts groan! The herds of cattle are perplexed because there is no PASTURE for them; even the flocks of sheep are dismayed." (Joel 1:18)

THIS PRODUCT IS DEDICATED TO MY MOM, DAD, WIFE, AND COUNTRY.

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Grazing trials were conducted at the University of Florida Agricultural Research Center, Ona, Florida, in 1976 and 1977 to study the effects of three stocking rates (SR) (7.5, low; 10, medium; and 15, high; cattle/ha) and the associated grazing pressures on yield, quality, forage utilization, stubble carbohydrate reserves and cattle performance of three African stargrasses namely 'UF-5' and 'McCaleb' (Cynodon aethiopicus Clayton and Harlan) and 'UF-4' (Cynodon nlemfuensis Vanderyst). Additionally, the medium stocking rate was imposed on 'Transvala' digitgrass (Digitaria decumbens Stent.) and 'Pensacola' bahiagrass (Paspalum notatum Flugge).

All pastures received one uniform application of 0-44-88 kg/ha (N-P_2O_5-K_2O) and a total of 220 kg/ha N in three split applications, annually.

The two-year seasonal forage production averaged over all stargrasses was 17.0 metric tons/ha at the low, 18.3 at the medium, and

20.1 at the high SR. The lower yield with decreasing SR was attributed to the existence of a greater metabolic sink in the standing residue under lenient grazing pressure. Net dry matter production was estimated at 15 and 10 metric tons/ha on digitgrass and bahiagrass, respectively, at the medium SR.

In vitro organic matter digestion (IVOMD) of stargrass forage on offer ranged between 44 and 54%, exhibiting a positive linear response to increasing SR. The IVOMD of digitgrass (51%) was very similar to that of UF-5 stargrass but superior to UF-4, and McCaleb stargrasses and bahiagrass. There was no difference in crude protein content among the five entries of tropical grasses which averaged 9.9%.

Utilization of seasonal dry matter yield by cattle varied from 75 to 95% and was directly related to SR. However, intake at the high SR (7.6 kg DM/cattle/day) was lower than those at the lenient grazing pressures (9.3 and 10.2 at the medium and low SR, respectively). Forage dry matter consumed annually at the medium SR averaged 16.7 metric tons/ha for the stargrasses as compared with 14.9 on digitgrass and 9.9 on bahiagrass.

Total nonstructural carbohydrate (TNC) reserves in grass stubble and roots exhibited a marked quadratic response to grazing. A regrowth (rest period) of 28 days was sufficient to replenish the depleted TNC on all treatments except digitgrass in the fall season. The concentration of TNC reserves was much higher in the roots than in the stubble of stargrass. However, TNC was greater in the stubble than in the roots of digitgrass, and higher in the rhizomes than

roots of bahiagrass. The minimum TNC levels in both the roots (6.8 to 7.5% on DM basis) and the stubble (4 to 5%) of stargrasses were observed at the high SR. Bahiagrass rhizomes contained the highest level of TNC (23%).

Cattle average daily gains (ADG) from 0.18 to 0.56 kg/day on stargrasses were an inverse linear function of stocking rate, a linear function of available forage or residue (metric tons/ha) and a nonlinear function of grazing pressure (kg DM/100 kg BW/day). The minimum grazing pressure required to obtain maximum ADG on stargrass ranged from 6 to 7 kg available DM/100 kg BW/day or the accumulation of 2 to 4 kg residue/100 kg BW/day based on varietal differences. Beef gains per hectare averaged over 2 years on stargrass were 470 kg/ha at the high SR, 617 at the medium, and 576 at the low.

Although there was no statistical difference in ADG on stargrass (0.35 kg/day) compared with digitgrass (0.28 kg/day)or bahiagrass (0.22 kg/day), these rates of gain created significant differences in total beef gain/ha in 1976, which varied from 580 kg/ha on stargrass, 461 on digitgrass to 369 on bahiagrass, all measured at the medium SR.

Coleman Y. Ward

Chairman

INTRODUCTION

Tropical and subtropical areas of the world hold the greatest potential for forage and, therefore, cattle production because of favorable temperatures and high rainfall patterns. These same areas also have been richly endowed with a broad-spectrum germplasm of forage grasses and legumes capable of high yield potential during the entire year. However, many tropical grasses under native range conditions exhibit a lower feeding value due to a rapid decline in quality with maturity, which would discourage the stockpiling of forage. Consequently, the year-round quality of available forage is usually one of the constraints to animal production in the tropics. This constraint is overcome partially by some combination of intensive cultural and managerial practices applied to the soil-plant-animal complex.

Nevertheless, animal production in the tropics remains an extensive operation based primarily on native grasslands with little fertilizer inputs, and to a much lesser extent on improved grasslands. In order to realize high animal production per unit of land area from forages, it is necessary to utilize forages that possess high quality and high yield, which requires appropriate grazing management systems. For example, under intensive management of tropical grasses, Vincente-Chandler et al. (1974) reported yields of over 230 metric tons per hectare yearly of high quality green forage. The report

also indicated that intensively managed tropical grasses carried over five - 272 kg animals per hectare throughout the year producing over 1100 kg of gain. Practices recommended to obtain these high yields from forages include estatablishing grasses of high yield and quality potential, adequate fertilization and liming, weed control, and proper forage and animal management.

The need for a broad-based germplasm of persistent, high yielding, and good quality perennial forage grasses adapted to subtropical peninsular Florida has received much attention during the past 40 years. Through variety testing and screening under intensive grazing management, several tropical grasses appear to have considerable grazing potential. A number of stargrasses, namely 'UF-5' and 'McCaleb' (*Cynodon aethiopicus* Clayton and Harlan), and 'UF-4' (*Cynodon nlemfuensis* Vanderyst) appear promising with respect to their production, cold tolerance, quality, and persistence. But bahiagrass (*Paspalum notatum* Flugge) and 'Pangola' digitgrass (*Digitaria decumbens* Stent.) continue to serve as the most important pasture grasses in south-central Florida, even though their performance is questionable at times.

To determine the ultimate performance of a pasture grass it is necessary to test that species under grazing conditions and to measure animal production. In the context of grazing management, length of grazing period, duration of rest period, and stocking (or grazing) pressure are the three most important factors. The response of a pasture species to the independent effects as well as the interactions among these factors should be known if appropriate recommendations are to be made on grazing management. Consequently, this research

was conducted to study the effects of low, medium, and high (7.5, 10 and 15 cattle per hectare, respectively) stocking rates on the performance of UF-5, UF-4, and McCaleb stargrasses. In addition the medium stocking rate was imposed on 'Pensacola' bahiagrass and 'Transvala' digitgrass as a benchmark.

The following objectives were set forth: 1. To determine the effect of stocking rate on dry matter yield, in vitro organic matter digestion (IVOMD), crude protein content and consumption of the five grasses. 2. Determine the total nonstructural carbohydrate fluctuations in the stubble and roots of the grasses, following various stocking rates during a grazing cycle and growing season. 3. Estimate cattle average daily gain and gain per unit land area as influenced by stocking rate and grazing pressure.

REVIEW OF LITERATURE

Forage Evaluation

The soil-pasture-animal system is so complex that it is always difficult to study all its underlying mechanisms. Hence, Humphreys (1966) wrote that "the management of veld is an art, which can only be guided by scientific findings" (P. 93). However, considerable progress in pasture and forage evaluation has been made during the past 40 years from concerted efforts of integrated disciplines which involve plant and animal nutrition, breeding, physiology, pathology, ecology, climatology, soils, statistics, and economics. A few tentative schemes for the logistics of pasture and forage evaluation have been suggested (Mott and Moore, 1970; Myers et al., 1974) in which the teamwork approach of many specialists is implicit. In the scheme proposed by Mott and Moore (1970), the plant breeder, the agronomist, the forage physiologist, the soil fertility specialist, and the animal nutritionist all play important roles. The scheme attempts to show the various steps from the agronomic evaluation sequence for forages to the point where the response by the animal is measured and, ultimately, systems of feeding are developed. Their scheme begins with the use of introduced forage plants or with local breeder's lines. These plant materials undergo a screening sequence involving small-plot clipping studies, uniformity tests, environmental evaluation under grazing (mob grazing), animal response experiments

in terms of product per animal and animal product per unit area, and finally, the use of the screened forage(s) in forage-livestock systems. Most phases of the scheme are accompanied by quality evaluations of the forage(s) by *in vitro* methods.

Clipping Compared With Grazing Experiments

According to Chamblee (1962), the problems faced in forage evaluation are threefold: (1) those largely independent of the effect of animals, (2) those in which the investigator needs to determine the influence of the animal on the sward but does not necessarily need to determine the effect of the sward on the animal, and (3) those which can be solved only by evaluation with the animal. Generally, the first two types of problems are studied in relatively small plots, whereas the third type needs relatively large pastures.

Defoliation is a term used in both clipping and grazing experiments to imply partial removal of plant shoots. Defoliation is categorized variously in terms of its frequency or time interval between defoliations; intensity of defoliation is measured by the proportion of the plant removed and the characteristics of the remaining material after defoliation; time of defoliation may be considered in relation to the developmental stage of the plant or plants, the tiller population and its age, the carbohydrate status of the plant, and the nature of current environmental conditions (Humphreys, 1966).

Many fundamental problems of establishment and maintenance of forages could be solved without the use of animals, whereas other

problems may be best and frequently only solved with the use of the grazing animal. Small plots are extremely valuable as a means of obtaining certain basic information on the soil, climate and management requirements of forages. The dangers of extrapolating results from clipping experiments to grazing practice have received much consideration by pasture scientists. While both forage yield and quality are readily influenced by grazing and cutting practices, cutting and grazing affect the response in different magnitudes. Blaser et al. (1969), Larsens and Johannes (1965), and Vincente-Chandler et al. (1974) have demonstrated that, in general, yields of grazed swards are lower than those of the same swards under clipping situations. Keya (1974) studied for four years the effect of clipping and grazing on swards of Setaria sphacelata (Schum) Stapf cv. Nandi with and without N fertilization or in mixture with either Desmodium intortum Mill. or D. uncinatum Jacq. where all treatments were cut at eight-week intervals. Contrary to the general rule, he found that cut and grazed swards gave about the same dry matter yield during the first year. However, in the subsequent years, the dry matter yields of the grazed plots were considerably higher than the cut plots.

Chamblee (1962) pointed out that, in clipping trials, many investigators try to simulate grazing with a mowing machine or similar mechanical means and that much information on the effect of different intensities of defoliation and other management variable could be obtained this way. However, he cautioned the investigator in selecting the mechanical means for harvesting and even more so in the

interpretation of the data. Chamblee (1962) indicated that trampling, biting off of the forage selectively, the urine and feces, and soil compaction contribute to most variations between grazed and clipped pastures and that data obtained by simulated grazing with the mowing machine often cannot be applied directly to grazing conditions. Hodgson (1974) deplored the shortage of information on the production and utilization of herbage under grazing and of direct comparisons of cutting and grazing. Therefore, it is evident that different species, either in pure or mixed stands, react differently to clipping or grazing treatments and that extrapolation of results from clipping experiments to grazing practice usually is unsound.

Net Production

Forages are grown for the animals and because of their value, the animals should have priority over the plants. However it is desirable to maintain optimum relationships between the plant and animal factors. It is unfortunate, therefore, that the majority of literature on the effect of grazing management and stocking rate have given very little consideration to what happens to the pasture sward in terms of its total yield, quality, longevity, and botanical composition. Much of this kind of information has accrued from clipping experiments dealing with intensity of sward defoliation (Wheeler, 1969, 1962; Humphreys, 1966), a practice which generally gives misleading results. Another difficulty, arising from the fact that the pasture situation involves two basic biological systems, is

the choice of a generally acceptable yield unit. Pasture yields, for instance, are variously reported in tons of hay equivalent or DM, animal unit months (AUM's) or carrying capacity, beef or milk produced per day and/or hectare, or as nutritional components such as total digestible nutrients (TND) and protein (Jacobs, 1973). Even seemingly simple measures such as tons of forage are complicated by differing DM percentages, shrink, and harvest losses.

Determination of Yield

The measurement of net primary production, by measuring the biomass of the plant community at the beginning of a study period and again at the end, allowing the correction for growth by the difference technique has been widely used and recommended (Milner and Hughes, 1970). However, sampling to estimate yield remains one of the most difficult techniques involved in pasture research. The highly variable nature of herbage yield renders accurate sampling difficult and relegates to a laborious task, yield estimations of the amount of forage on offer to the grazing animal. The determination of the number of samples required for accurate estimate of forage yield (Tothill and Peterson, 1962) and methods devised to reduce cost and save time (Hansen et al., 1953) are important considerations in accomplishing this necessary task.

Various techniques have been developed to reduce cost and time of sampling. The "Double Sampling Procedure" recommended by Hanson et al. (1953) involves the use of a ratio or regression estimate of an independent variate, highly correlated with the variate being estimated. Pechanec and Pickford (1937) have obtained a correlation

coefficient of 0.919 between visual estimation of the existing dry matter and actual weight determinations under range conditions. Evans and Jones (1958) obtained significant correlation coefficients by using plant height times ground cover to estimate yield of animal ranges in California.

With improved pastures, Wilm et al. (1944) judged the line transect method superior as compared with visual estimates of yield. In New Zealand, Fletcher and Robinson (1966) demonstrated the capacitance meter as being able to account for approximately 90% of the variation in forage yield estimates either as wet, dry or organic matter. For different pasture types, individual prediction equations were suggested (Campbell et al., 1962). Mott et al. (1965) adapted the beta ray attenuation technique to estimate forage yield _in situ_, and found that the instrument readings were unaffected by either crop or moisture variables in determining beta attenuation coefficients. Barta and Teare (1968) observed that only one standard yield calibration curve was needed to estimate green forage yields at any moisture percentage. Neal and Neal (1973) presented a review of the advantages and limitations of several types of forage meters for the nondestructive estimation of forage yield. The idea of estimating bulk density (Alexander et al., 1962) and its expression as a function of density and height (Teare and Mott, 1965) prompted the development of the calibrated disc of Phillips and Clarke (1971). The disc is lowered onto the vegetative canopy under standardized conditions. The height, density, and nature of the vegetation creates a resistance which keeps the disc from reaching the ground level.

Calibration coefficients are required for each type of pasture generated from double sampling and comparing with harvested sample yields. In passing, it needs to be pointed out that all methods of estimating forage yield besides harvesting would require prior calibration. Moreover, since all methods for estimating total yield or yield of component species are based upon the relation: yield/unit area = function (density, height), the height of cut herbage contributes significantly to herbage yield (Teare and Mott, 1965).

Botanical Analysis

Literature contains numerous results of forage species and pastures evaluated by grazing and/or cutting. Where pastures make up the main source of feed for the grazing animal, botanical stability is desired. Wagner (1952) pointed out that botanical composition is particularly important in studying the effects of various treatments on seasonal and year-to-year trends in pasture production.

In the determination of botanical composition, every effort should be made to employ a method that will provide percentage composition data comparable to those based on weight as determined from hand separation of component species. Studies conducted on many kinds of grasslands indicate that the method of visual estimation of botanical composition may be a reliable procedure for studying flora. In their review on procedures and techniques for sampling grasslands, Brown (1954) and Tothill and Peterson (1962) showed that despite its subjectiveness, the visual estimation of percentage composition and/or weight *in situ* as the estimation of units of

weight for each species in the field is one of the better methods for surveying vegetation. A wide variety of tropical pasture mixtures was studied by Jones et al. (1968) to provide year-round grazing. Changes in botanical composition were determined by visual estimation every six weeks by trained operators, and the difference in mean composition for any component rarely differed by more than 5% between visual estimation and hand separation methods. On the other hand, Van Keuren and Ahlgreen (1957) concluded that results obtained from visual estimation methods are greatly influenced by the experience of the observer. Hunt (1964) reported that visual estimates of botanical composition of dried samples were extremely accurate.

Productivity of Tropical and Subtropical Forages

Tropical pasture species are the most recent additions to the range of plants available for pasture improvement. The high productive potential of tropical forage grasses gained recognition worldwide shortly after the release of 'Pangola' digitgrass (*Digitaria decumbens* Stent.) from South Africa in the early 1930's (Hodges, 1950; McCloud, 1956). Since then the number of tropical grass species under study has increased at a tremendous rate. For example in 1959, Vicente-Chandler et al. (1974) examined the effects of nitrogen fertilization and frequency of cutting on yields of three tropical grasses -- namely 'Napiergrass' (*Pennisetum purpureum* Schum.), 'Guineagrass' (*Panicum maximum* Jacq.) and 'Paragrass' (*Brachiaria mutica* (Forsk.) Stapf.). In the late 60's, while 23 entries of perennial subtropical grasses including cultivars, recent introductions

and breeder lines were undergoing screening at Florida (Hodges and Martin, 1975), evaluation of 40 tropical grass cultivars and 23 tropical legume cultivars was proceeding in Australia (Hutton, 1970). The concensus of experimental evidence is that, under the warm tropical or subtropical environment and intensive management, tropical grass species tend to be more productive and more highly persistent than their temperate counterparts (Cooper, 1970; Kemp, 1974). Vincente-Chandler et al. (1974) reported annual cut dry matter yields of 37, 33, 30, 30, and 28 metric tons/ha for Napiergrass, 'Congograss' (*Brachiaria ruziziensis* Evrard), 'Stargrass' (*Cynodon nlemfuensis* Vanderyst.), Guineagrass and Pangola digitgrass, respectively. Under grazing, dry forage actually consumed in a year was estimated at 13, 12, 13, 13, and 12 metric tons/ha following the same order of listed species. Fertilizer requirements are equally high in producing such high forage yields. Vincente-Chandler (1967) estimated that well fertilized grasses harvested by cutting in Puerto Rico, for example, removed an average of 322 kg of N, 53 kg of P (121 kg P_2O_5), 415 kg of K (499 kg K_2O), 125 kg of Ca and 74 kg of Mg per hectare yearly in the harvested crop.

The biochemical basis of a higher growth potential of tropical grasses was clarified by Hatch and Slack (1967) and called a C_4 pathway (since the first photosynthetic products are four-carbon acids) instead of the C_3 pathway described by Calvin (1962). The C_4 pathway has been identified mainly in the subfamily Panicoideae but also occurs in members of the subfamilies Chloridoideae and Bambusoideae.

Nutritive Value of Tropical Pasture

It is well accepted that if the animal potential remains invariant and if no additional feed is introduced into the forage-animal system, then output per animal is a function of the intake of digestible nutrients (Mott and Moore, 1970; Burton, 1970), and it is within this context that digestibility is recognized as an important measure of forage quality for ruminants.

Digestibility

In vivo digestibility, though the most reliable predictor, is also the most costly, time consuming and could be influenced by ruminant species, adequacy of available water, ambient temperature, and level of feeding (Riewe and Lippke, 1970). The two-stage *in vitro* digestion technique developed by Tilley and Terry (1963) or its modifications such as that by Moore et al. (1972) are highly correlated with *in vivo* digestion trials and are presently the most widely accepted procedures used to estimate forage digestibility (Mott, 1973). The *in vitro* technique is less time consuming, requires small forage samples, and enables a large number of forages to be studied in a short time. The difficulty in applying the *in vitro* technique to the pasture situation lies in the problem of simulating grazing such that forage samples collected would represent the animal's diet. For example, Smith (1974) observed that forage samples collected from oesophageal-fistulated steers had higher *in vitro* digestibility and N content and lower cellulose content than those samples cut by hand.

In general, disgestibility declines with advanced maturity of all forage plants (Homb, 1953; Reid et al., 1959; Riewe and Lippke, 1970; Minson, 1971; Moore and Mott, 1973; Van Soest, 1973; Coward-Lord et al., 1974). Some figures indicate that dry matter digestibilities of temperate grasses decline about 0.5 percentage units per day (Reid et al., 1959) the rate of decline being considerably less in the aftermath growth (Minson et al., 1964) while on the average a decrease of 0.1 to 0.2 digestibility units per day was reported (Minson, 1971) for tropical species. Minson had explained that the higher rate of decrease in digestibility units for temperate grasses may be a real one since tropical species start off at a lower digestibility than temperate ones but it could also be caused by the very much longer period over which the tropical pastures were studied, the nature of the decline being sigmoid rather than linear (Moore and Mott, 1973). Where young stages of growth have been compared over short periods of time, higher daily rates of fall in digestibility have usually been found for tropical species (Butterworth, 1961; Grieve and Osbourn, 1965; Minson and Milford, 1968). Riewe and Lippke (1970) pointed out that, at similar stage of maturity, warm-season perennial grasses are characterized by high cell wall contents with more lignin, and that the cell wall portion may increase rapidly from 50 to over 70% as the plant matures. Moore and Mott (1973) compiled selective data in which maximum DM or OM digestibility exceeded 65% in most cases and sometimes even higher than 80% in temperate grasses whereas for tropical grasses, the values were seldom higher than 65% and never greater than 80%.

Crude Protein

The quantity of forage eaten is primarily controlled by the extent and rate of digestion within the rumen (Balch and Campling, 1962). However, when a feed contains insufficient N, voluntary intake is reduced below that limited by rumen distension (Minson, 1967). Low N contents are common in mature native pastures in Australia and were considered to be the main cause of their poor quality (Christian and Shaw, 1951).

The critical level of crude protein required in a pasture before intake is reduced by nitrogen deficiency has been estimated at between 6.0 and 8.5% (Blaxter and Wilson, 1963; Milford and Minson, 1955; Minson and Milford, 1967). Values below this level have often been found in mature tropical grasses (Butterworth, 1967).

The evidence suggests that as crude protein content declines, digestibility also declines and both of these nutritive qualities are negatively correlated with increase in maturity or with a downward movement into the canopy of the pasture (Minson et al., 1964, Wilkinson et al., 1970). Working on six tropical grasses, Milford and Haydock (1965) have reported a nonlinear relationship between the decline in crude protein content and increase in maturity. The decline proceeded rapidly for a period of 40 to 60 days and then was much slower.

The application of N fertilizer to the sward, the inclusion of legumes or the feeding of N supplements are obvious ways of overcoming

any deficiency in N which may exist. Since the feeding value of tropical grasses near maturity can be limited by a deficiency of crude protein, late application of N fertilizer has been used successfully to raise the N content and intake of species like Cynodon dactylon (L) Pers. (Blue et al., 1961) and Digitaria decumbens Stent. (Krestchmer, 1965; Minson, 1967).

Physiological Response of Pasture to Grazing

When the foliar portion of a grass plant is removed by a mower or by a grazing animal, the growth of new tissue is initiated to replace the parts removed. The rate with which the regeneration of new top growth proceeds and the total amount produced are of great importance. This rate of recovery and total yield, although dependent to a large extent upon external environmental factors, are also influenced considerably by the intensity and frequency of defoliation as determined by management practices. Evidence has been offered by many workers (Canfield, 1939; Graber and Sprague, 1938; Harrison and Hodgson, 1939) that close and frequent clipping or grazing reduces the total yield of tops of forage plants.

Associated with the ability of the plant to produce new growth after defoliation is its chemical composition and morphology. It is generally accepted that when all environmental factors are favorable, the rate of recovery by the defoliated plant depends primarily on (1) the leaf area index and (2) the organic food reserves present in the tissue of the stubble (Graber et al., 1927; Sullivan and Sprague, 1943; Ward and Blaser, 1961), and to some degree on (3) the location

of the meristematic tissue that forms new shoots and leaves and (4) the morphological characteristics of species (Blaser et al., 1962). Blaser et al. (1962) pointed out that because of these factors, species are affected differentially by defoliation and methods of grazing utilization.

Plants that are defoliated by grazing or harvesting several times a year must maintain sufficient energy reserves in readily accessible form to regenerate new tillers. Carbohydrate reserves are thought to be used by plants as substrate for growth and respiration. Adequate carbohydrate reserves are important in perennial plants for winter survival, early spring growth initiation, and regrowth initiation after herbage removal when photosynthetic production is inadequate to meet these demands. Many pasture and range management practices are based upon knowledge of how various environmental factors and herbage removal treatment affect carbohydrate reserves. This understanding helps managers to maintain high yields of desirable species and to control undesirable species.

Graber et al. (1927) first defined reserve energy constituents as "those carbohydrates and N compounds elaborated, stored, and utilized by the plant itself as food for maintenance and for development of future top and root growth" (P. 1). These carbohydrates, termed "total available carbohydrates," are those available as energy to the plant (Weinmann, 1947). Smith (1969) suggested that the term "total nonstructural carbohydrates" (TNC) be used, because it is more applicable to both animal and plant investigations. Nonstructural carbohydrates -- reducing sugars (glucose and fructose),

nonreducing sugar (sucrose), fructosans and starches -- are the major reserve constituents. Structural carbohydrates -- hemicellulose (pentosans and hexosans) and cellulose -- are not considered to provide significant reserves (McCarty, 1938, Sullivan and Sprague, 1943; Weinmann, 1948). Type and distribution in the plant and relative proportions of the individual carbohydrate reserve components vary among and within grass species and under various climatic conditions during the growth season. Predominant carbohydrate reserves stored by temperate-origin grasses are sucrose and fructosans, whereas those of subtropical or tropical-origin grasses are sucrose and starch (Cugnac, 1931; Weinmann and Reinhold, 1946; Smith, 1968; and Ojima and Isawa, 1968).

Although Graber et al. (1927) originally defined reserve constituents as including nitrogenous compounds, most investigators generally have found that proteins are used in respiration but there is not a net utilization (Hackett, 1959). Smith and Silva (1969) found that proportionally fewer nitrogenous compounds than TNC (1:18) were translocated from roots of alfalfa (Medicago sativa L.) for production of new top growth after cutting in greenhouse trials. Alberda (1966) pretreated perennial ryegrass for a short period to change the plant's level of reserves. To obtain plants with low TNC, they were placed in nutrient solution in the dark at 30°C and to obtain plants with high TNC, they were placed in water at 15°C in continuous light. The pretreatment changed the amount of nonstructural carbohydrates but did not change the amount of organic nitrogenous compounds.

Nonstructural carbohydrates may be stored temporarily in all plant parts. Many scientists in the past concluded that underground organs were the major storage region for carbohydrate reserves (Weinmann, 1948; Troughton, 1957). Several other studies have revealed that the major storage region is generally in the stem bases (which includes stolons, corms, and short rhizomes), not in roots per se (Sampson and McCarty, 1930; Smelov and Morazov, 1939; Sullivan and Sprague, 1943; Baker and Garwood, 1961). The decrease of carbohydrate reserves in the roots of orchardgrass, after severe herbage removal accounted for less than one-tenth of root respiration (Davidson and Milthrope, 1966). They concluded that transfer of carbohydrates reserves from the shoots, remobilization of other substances in the roots, or both must have occurred to account for root respiration. Marshall and Sagar (1965), using autoradiographs and labelled CO_2, found that nonstructural carbohydrates in the roots of Italian ryegrass (Lolium multiflorum Lam.) were not mobilized to the shoots to support regrowth following herbage removal, nor were labelled compounds translocated to the roots from the shoots when a part of the herbage was removed from all tillers. They concluded, "The classical view of a transference of compounds from the root to shoot following defoliation (Troughton, 1957) -- seems unlikely in perennial grass without special storage organs" (P. 371).

The accumulation of carbohydrate reserves in plant tissue is a dynamic system of energy balance between photosynthesis and respiration. The carbohydrate reserves of orchardgrass and bermudagrass grown in growth chambers decreased when growth and respiration demands were

greater than photosynthetic rate and increased when growth and respiration demands were less than photosynthetic rate (Blaser et al., 1966). Hence, the level of reserves is determined by growth rate, plant development stage (Hyder and Sneva, 1959), and environment (Troughton, 1957). In Indiana, bromegrass (Bromus inermis Leyss.) utilized almost one-third of the TNC in the herbage during the night, but diurnal fluctuations for other grass species were less (Holt and Hilst, 1969). For the grass species studied TNC concentration in the herbage was lowest at 6 am, and increased linearly to a high at 6 pm. The seasonal variation of carbohydrate reserves differs among grass species. In many grass species, the reserve level is lowest when the second or third leaf emerges (about 1 month after the start of plant growth), but in other species, the reserve level is lowest after seed ripening (Jameson, 1963). Carbohydrate reserves of Colorado wildrye (Elymus ambigus Vasey) and mountain muhly (Muhlenbergia montana Scribn.) decreased during fast growth and increased during slow growth (McCarty, 1935). Hence, temperature and the availability of water and nutrients affect the seasonal variation of carbohydrates reserves inasmuch as they influence growth.

The effect of temperature on the percentage of carbohydrate reserves in the stem bases is determined by the origin of the grass species. Optimum temperatures for growth and net photosynthesis by temperature-origin grasses are about 20 to 25°C, whereas those for tropical-origin grasses are about 30 to 35°C (Evans et al., 1964; Treharne and Cooper, 1969). In another study, the relative growth rates of warm-season grass species were highest at 36°C day/31°C

night temperatures and decreased about 75% as temperatures were reduced to 15/10°C (Kawanabe, 1968). In contrast, relative growth rates of cool-season species were highest between 21/16 and 30/25°C and decreased about 40% as temperatures were increased to 36/31°C (Balasko and Smith, 1971). This difference in temperature optima between tropical and temperate grasses results from differences in temperature optima of the major CO_2-fixing enzymes (Treharne and Cooper, 1969). The activity of ribulose-1,5-diphosphate carboxylase is higher in temperate-origin grasses while the activity of phosphoenolpyruvate carboxylase is higher in tropical-origin grasses. Temperate-origin grasses, therefore, contain only the Calvin (C_3) photosynthetic pathway, while tropical-origin grasses contain both the C_4 (Hatch and Slack, 1967) and C_3 photosynthetic pathways. In tropical-origin grasses, the C_4 pathway is located in chloroplasts of mesophyll tissue, which surrounds the C_3 pathway located in chloroplasts of bundle sheath tissue, an arrangement that greatly improves their CO_2-fixing efficiency over temperate grasses (Berry et al., 1970; Kortschak and Nickell, 1970).

The effects of water stress (Eaton and Ergle, 1948) and N fertilization (Weinmann, 1948) on carbohydrate reserves are complex and variable. Some scientists have reported that drought increased the carbohydrate reserves in several grass species (Julander, 1945; Brown and Blaser, 1965; Blaser et al., 1966), others have reported that drought decreased carbohydrate reserves (Bukey and Weaver, 1939). Evidently the degree of water stress and the plant

growth stage during which it occurs will variably affect carbohydrate reserve levels. If the water stress stops stem elongation and has only minor effects on photosynthesis, as reported by Wardlaw (1968), carbohydrate reserves would then increase. Brown and Blaser (1970) suggested that the buildup of carbohydrate reserves and inorganic N in plants under water stress results from the transformation of carbon-containing nitrogenous substances. Studies to date generally show that N applied at low to moderate rates increase carbohydrate reserves through its effect on increasing leaf area, chloroplast protein and chlorophyll content and, hence, increased photosynthesis (Murata, 1969). Excess N applied during periods of water stress and high temperatures coupled with frequent herbage removal often reduced stands and growth rate (Drake et al., 1963; Colby et al., 1965; Klipple and Retzer, 1959). A possible explanation that excess N fertilization stimulates the synthesis of amino acids and amide compounds to the detriment of carbohydrate reserves was offered by Prianishnikov (1951).

The effects of clipping on plant regrowth has been classified into three simplified categories: Herbage removal reduces (1) amount of carbohydrate reserves, (2) root growth, and (3) leaf area (Alcock, 1964). May (1960) challenged the importance of carbohydrate reserves in controlling regrowth rate following herbage removal. New research techniques since then have conclusively implicated carbohydrates in the regrowth mechanism following clipping. Ehara et al. (1966) showed that carbohydrate reserves assimilated as

labeled CO_2 by bahiagrass were used up to help form leaves for six days after herbage removal. Labeled nonstructural carbohydrate in alfalfa (labeled by $^{14}CO_2$ assimilation) which were initially stored in the root and crown were utilized after herbage removal as substrate for respiration of booth roots and tops and as structural components for top growth (Pearce et al., 1969; Smith and Marten, 1970). White (1973) in his review has pointed out that the discrepancies which exist as to whether carbohydrates contribute to regrowth are due to the following factors: (1) variation in amount and capacity of photosynthetic tissue remaining after herbage removal; (2) sampling for reserves too late after clipping, when the reserves have already been restored; and (3) sampling the wrong plant part. In general, the level of carbohydrate reserves in the lower regions of the stems apparently affects the regrowth rate for two to seven days following herbage removal; but this initial support from carbohydrate reserves can be maintained during subsequent exponential growth.

The effects of grazing and clipping on carbohydrates are similar but not identical. Grazing reduces plant vigor more than clipping at the same degree of herbage removal. Grazing causes removal of all herbage from some plants and not others; therefore, the ungrazed plants take available nutrients and water away from grazed plants (Mueggler, 1970). However, grazing may be less detrimental than clipping if some ungrazed tillers are allowed on a plant while others are removed, thus allowing for the transfer of carbohydrates from ungrazed to grazed tillers. For example, carbohydrate reserves of

tall fescue in Missouri increased as the unclipped tillers per plant increased from 0 to 30% (Matches, 1966) and carbohydrate reserves of dallisgrass (Paspalum dilatatum Poir.) in Mississippi also increased as the unclipped tillers increased from 0 to 10% (Watson and Ward, 1970).

Various management practices -- range readiness, season of use, degree of utilization, and grazing systems -- are partially based upon how they affect carbohydrate reserves of grasses (National Research Council, 1962). The effects of various management practices on plant vigor can be partially measured objectively and quantitatively with percentage of TNC (Cook, 1966; National Research Council, 1962). Knowledge of the seasonal variation of carbohydrate reserves and effects of climate and management practices on them will help pasture and range managers improve present management practices. Cook (1966) stated that "proper management does not necessarily imply that a maximum level of carbohydrate reserves be maintained, but care must be taken that these reserves do not fall below a critical level" (P. 44) or tillers will die. More research is therefore needed to determine critical levels of carbohydrate reserves at which some tillers die for the different pasture species available.

The Pasture-Animal System

Pasture and Animal Potentials

Forages must be consumed and converted to animal products to be of value. Pasture production could thus be viewed as an interrelationship of two basic biological systems, "pasture sward" and the "grazing

animal" (Matches, 1970). Production per animal and per unit land area, therefore, are conditioned to any factor influencing either of the two systems. Mott (1973) has characterized the forage production per unit area of land in terms of feed units as the "quantity" aspect of animal production and the response of the animal to the pasture as the over-all measure of its "quality" provided animal potential is a constant and pasture is the only source of unlimited feed supply to the animal.

The concept of animal and grassland potentials originating from Ivins et al. (1953) led Matches (1970) to define pasture potential as the maximum amount of forage available to the grazing animal and, if all the grazeable herbage is consumed, the pasture potential is reached. Animal potential for production is realized only when all grazing animals on the pasture are performing at their maximum capabilities under the prevailing conditions of grazing management (Matches, 1970). Pasture potential, as relates to animal production, is affected by the amount of forage available and its quality which in turn is dependent upon the pasture botanical composition, stage of growth, fertilizer treatment, rainfall, management practices, and all other factors influencing forage production (Ivins et al., 1958; Mott, 1973). The animal potential on the other hand is governed by the type and genetic makeup of the livestock, health, previous treatment, age, sex, size, environmental effects, and all other remote factors that influence animal production. The connecting links between the two potentials are primarily the rate of stocking, appetite of the grazing animals, and palatability of the herbage which might, under conditions of low palatability, impose a restriction on intake and hence animal production.

Maximum production per animal and per land area cannot be obtained concurrently. Thus, efficient forage utilization for animal products demands wise compromises between production per animal and land unit. Ivins et al. (1958) commented that most frequently, our techniques of grassland evaluation with livestock tend to measure either the animal potential or the grass potential depending on whichever one is limiting in the animal-pasture complex. These authors presented situations where pasture potential exceeds animal potential, where they are equal (very rare), and where animal potential exceeds pasture potential, and their implications in responses obtained from pasture-animal systems in grazing experiments. For example, in order to measure any responses (in terms of animal production) from treatments such as fertilizers or irrigation, animal potential must be adjusted through rate of stocking to exceed the pasture potential otherwise available forage is left unutilized. It then becomes necessary to talk about optimum situations and not maximum potentials. Mott (1973) indicated that optimum grazing or (stocking) pressure be considered as an optimum range which is a compromise between output per animal and output per unit area. The same author also emphasized that the concept of optimum grazing pressure relates only to animal output and does not take into consideration the optima for plant species in the pasture. For persistence of certain forage species a lower grazing pressure than the optimum, even into the undergrazing range, may be required. A detailed consideration of stocking rate and grazing pressure as they relate to animal production is given below.

Stocking Rate, Grazing Pressure, Carrying Capacity and Their Relationship with Animal Production

The use of the terms stocking rate, grazing pressure and carrying capacity occur repeatedly in pasture-grazing research and should therefore be defined. Definitions from Mott (1966) areas follows:

Stocking Rate is the number of animals per unit area of land, the term bearing no relationship to the amount of forages;

Grazing Pressure is the number of animals per unit of available forage or the converse and;

Carrying Capacity is the stocking rate at the optimum grazing pressure.

Mott (1960) also mentioned that "grazing intensity" may be used as a synonym for grazing pressure and "grazing capacity" as a synonym for carrying capacity.

The general relationships of increased stocking rate to production per animal and production per unit area have been extensively discussed in the literature. Generally, increasing the stocking rate up to some point results in a decrease in output per animal, but an increase in production per unit area (McMeekan, 1956, 1960; Harlan, 1958; Mott, 1960, 1973; Riewe, 1961, 1965; Hull et al., 1961, 1965; Petersen et al., 1965; Conway, 1965, 1968; Vivian 1966; Browne and Walshe, 1968; Jones and Sandland, 1974; and Connolly, 1976). However, much controversy remains on the linearity or otherwise of the "true" relationship between stocking rate and animal gain.

McMeekan (1965) emphasized the importance of stocking rate compared to kind of grazing management systems and kind of stock in the conversion of pastures to animal products. He considered stocking rate to be the most powerful device affecting the efficiency of pasture conversion to animal products on per unit area basis. Harlan (1958) made the first attempt at expressing the generalized relationship between stocking rate and liveweight gain per animal and animal product per unit area. He divided the range of stocking rate into light, moderate, heavy, and very heavy. From his proposed "double exponential" equation for gain per animal he predicted the following: (1) one full degree of grazing increment beyond heavy stocking rate will invariably result in loss of weight; (2) livestock must either gain or lose weight, i.e., an equilibrium could not be established by manipulating stocking rate; (3) the heavy stocking rate will yield a higher per unit area of land than moderate or light, since higher gain per head at moderate and light stocking rates was insufficient to compensate for the smaller area per head at the heavy stocking rate; and (4) gain per head on heavily grazed pastures should generally be more variable than on moderate or light stocking rates.

Mott (1960) pointed out that it would be inappropriate to suggest actual values for the constant in the equation presented by Harlan (1958) for the stocking rate-gain/animal relationship, except for specific sets of data, since the shape of the product-per-animal curve would differ for different ratios of feed requirements for maintenance to feed requirements for performance. The optimum grazing pressure concept then was submitted (Mott, 1960):

$$Y' = K - ab^{X'}$$

Where

Y' = the ratio of product per animal to the product per animal at the optimum grazing pressure.

X' = the ratio of stocking rate to the stocking rate at the optimum grazing pressure

and K, a, and b are constants.

Subsequently, a generalized curve was proposed for gain per unit land area of the form:

$$Z' = X'Y'$$

where Z' is the ratio of gain per unit land area to the gain per unit land area at the optimum grazing pressure. The relationships mentioned above mean that if a pasture is stocked below the optimum rate, higher gain per animal will result, and at light stocking rates, stocking rate has very slight effect on gain per animal over a wide range. Stocking rates higher than the optimum will greatly affect performance per animal because feed supply is reduced and selectivity declines considerably to the point where all feed produced in the pasture is consumed for maintenance and gain per animal will be zero. Mott (1960) also suggested that the optimum stocking rate could only be defined as an optimum range and that this stocking rate is somewhat lower than that which will give maximum product per unit area.

Riewe (1961) reviewed several grazing studies selected across the United States to develop a relationship between stocking rate and liveweight gain. His relationship denotes that animal gain is increased as stocking rate is decreased. But a point is reached

where further reduction in stocking cannot result in any further increment of animal gain. At this point, should further reduction in stocking rate result in forage becoming rank and advanced in maturity, it could as well decrease animal gain. Riewe's (1961) work also points out that the stocking rate at the point of no gain is approximately twice the stocking to produce the maximum gain per unit area of land.

Petersen et al. (1965) proposed a theoretical expression in which gain per animal is constant as stocking rate is increased to a "critical" point and beyond this point gain per head is inversely related to stocking rate. On the other hand, gain per unit area increases linearly as stocking rate is increased to the "critical point" and then decreases linearly with further increases in stocking rate. The critical point is defined as the stocking rate at which total forage consumed is exactly equal to the total grazeable forage, providing all animals are grazing at maximum capacity. This concept as pointed out by Matches (1970), is similar to the "animal potential" and "grassland potential" suggested by Ivins et al. (1958). For example, until stocking rate is increased to the "critical point," the grassland potential exceeds the animal potential. Cowlishaw (1969) elaborated on the theory developed by Petersen et al. (1965) by indicating that their conclusions on gain per animal applies only to an instantaneous situation because in practice the available forage is not of uniform composition, selection takes place, and therefore, the digestibility of the forage consumed declines with

increases in stocking rate. Moreover, the requirements for maintenance of the grazing animal also change as they grow and fatten. Mott (1973) reemerged with a more elaborate version of the concept of optimum grazing pressure, with the generalized curve, to represent a more realistic and practical situation. He reemphasized that the optimum grazing pressure must be considered as an optimum range and not as a "critical point" and that such an optimum relates only to animal output but excludes optima for plant species in the pasture.

Jones and Sandland (1974) compiled the results of several grazing trials from both temperate and tropical regions to derive their relationship, quite similar to that advocated by Mott (1960, 1973), in that their results were expressed on a common basis by calculating the optimum stocking rate and relating ratios of gain to ratios of stocking rate relative to that at the optimum. They proposed a linear relationship between stocking rate and gain per animal in accordance with those found by Harlan (1958), Riewe (1961) and Cowlishaw (1969). The proposed equation was:

$Yg = a - bX$ where Yg is the gain per animal, X is the stocking rate, and a and b are constants. The relation between gain per unit area (Y_u) and stocking rate (X) would then be:

$$Y_u = aX - bX^2$$

In accordance with the laws of differential equations, the authors indicated that the maximum gain per unit area occurs when $X = a/2b$.

Recently, Connolly (1976) has issued some strong comments about the linear equations and their supposed "simple qualities" as presented by Jones and Sandland (1974) as well as earlier linear models.

In his paper, Connolly examined the biases involved in the estimation of optimum stocking rate by Jones and Sandland (1974). He then proceeded to charge them with assuming linearity even in situations where the true relationship was quadratic and warned against the problems that could arise in the estimation of important parameters in grazing experiments from adopting their model. Connolly also provided experimental evidence involving five stocking rates where using within herd variation as error, the quadratic term was negative and significant at the 5% level of probability when gain was regressed on stocking rate and the square of the stocking rate.

Despite the fact that details of the exact equation remains unresolved, the weight of the above experimental evidence supports the contention that increases in stocking rates to the optimum range would result in substantial increases in animal production per unit area at the expense of individual animal production. If the optimum stocking rate under any set of conditions is established, stocking rates could be adjusted towards efficient production goals.

Fixed and Variable Stocking Rates

Grazing experiments fall in two major categories -- those in which the number of stock per unit area is fixed for a period of at least several months, and those in which it is varied on the basis of forage availability (Wheeler et al., 1973).

In the simplest of experiments using a range of fixed stocking rates, the levels in the range are chosen by the experimenter at the beginning of the trial to straddle the anticipated optimum stocking rate for the grazing season, whether the 'season' is restricted by

the climate to a few months or year-long. Wheeler (1973) indicated that if the study is to continue for more than one year, there are benefits in using the same stocking rates in each year, provided the range has been correctly chosen. However, because of difficulties often encountered with between-year variation, annual changes in rates may be desirable provided that at least one rate is common to permit adjustment for the year effect. Discussions on achieving different stocking rates by the use of varied plot size, flock or herd size or both, and on considering the interval between stocking rates in terms of animal/unit area or units of area/animal are given by Petersen and Lucas (1960), Morley and Spedding (1968), and Shaw (1970). Since the number of animals per pasture is a major factor determining experimental error per pasture in fixed stocking, it is appropriate for experimental planning to think of pasture size in terms of animals. Petersen and Lucas (1960) suggest that for quality measurements like average daily gains, pastures that will carry three to six animals appear to be of optimum size. For quantity measurements such as yield of Estimated Total Digestible Nutrients (ETDN), pastures which will carry one to three animals for the duration of the trial are optimum. When considering both quality and quantity measurements jointly, pasture that will carry from two to five animals is recommended to be optimum.

In the variable stocking rate procedure also known as put-and-take (P & T) grazing, the stocking rate is varied by the experimenter as frequently as the availability of the forage requires. The traditional P & T method, in which stocking rate is intentionally

varied to maintain a constant grazing pressure, was first described by Mott and Lucas (1952) and subsequently in more detail by Lucas (1963), Petersen and Lucas (1968) and Matches (1970). This method makes use of two categories of stock. Blaser et al. (1956) suggested the term 'testers' to represent the kind of animals about which inferences are to be made and are also used to measure quality of forage available and which remain on the experimental plots for the full grazing season. The other category comprises animals, put onto the plots when available forage exceeds the 'testers' daily requirements or taken off and placed on similar forage elsewhere as available forage declines, called 'grazers' or 'regulators'. Three methods of computing yields from raw data obtained in P & T experiments have been described (Mott and Lucas, 1952; Lucas, 1962; Petersen and Lucas, 1968; Matches, 1970), namely (1) using the data from all animals on a given treatment to obtain average daily performances for periods of suitable length, multiplying this by the total number of grazing days recorded in the period for testers and grazers (if used), to give the yield of animal product/unit area, (2) obtaining data on production per head from the testers for periods during the grazing season, and multiplying this by the total number of grazing days in each period, and (3) calculating the energy required for maintenance and production by all the animals that have grazed a plot, expressing this as effective feed units (EFU) (Lucas, 1962; Petersen and Lucas, 1968) and dividing by the estimated daily EFU requirements for maintenance and production of testers for each treatment

to give the carrying capacity in tester grazing days for the treatment. Output per hectare is then tester grazing days per hectare multiplied by the mean daily production of the testers. EFU may be expressed in a number of units such as digestible dry matter, metabolizable energy, net energy, starch equivalent or total digestible nutrients.

Whether to use a variable or fixed rate of stocking in pasture experimentation is a topic on which investigators often disagree and many papers have elaborated on the advantages and disadvantages of both methods. Proponents of the P & T method contend that representative comparisons between pasture treatments are obtained only when grazing pressure is maintained at uniform levels within all treatments and across all treatments (Blaser et al., 1956, 1959, and 1960; Lucas, 1963; Mott, 1960; and Mott and Lucas, 1952). Those objecting to the use of the P & T method do so on the basis that variable stocking rate is not practical on a farm basis (Morley and Spedding, 1968; Stobbs and Joblin, 1966; and Wheeler, 1962); that it may produce unreliable results due to the subjectiveness involved in adjusting the stocking rate of individual pastures according to the amount of forage which appears to be available (Alder, 1965; Kennedy et al., 1958, 1959; and Wheeler, 1962); and to the possibility that the larger number of animals in some pastures may lead to greater or smaller intake of herbage due to competition between animals (Alder, 1959). Some investigators prefer the use of several fixed rates of stocking for each treatment comparison rather than the use of the P & T method (Alder,

1965; Browne, 1965; and Wheeler, 1962). Alder (1965) contends that if the P & T method is used, animals should be added or removed in fixed numbers (either for each treatment or throughout the experiment) so as to avoid differential treatment effects. According to Kennedy et al. (1958, 1959), valid comparisons of animal production per unit area are made only when each treatment is stocked at the maximum carrying capacity at which a desired level of animal performance is maintained. He stated that the maximum carrying capacity of every treatment cannot be objectively determined. He suggested that every treatment should be stocked initially at the same rate and gradually increased until daily production per animal on one or more treatments starts to decline below the desired level of animal performance. Then the stocking rate of those treatments can be adjusted to a level that will maintain animal production slightly below the desired level.

Most of the controversy on either P & T or fixed stocking seem questionable. For example, the argument that farmers and ranchers cannot apply the practice of varying animal numbers may be true; however, alternative methods which are applicable at the farm level have been presented by others (Lucas, 1963; Mott, 1960; and Mott and Lucas, 1952). Generally they included harvesting excess forage for silage or hay during flush growth periods for feeding back during periods of limited growth; subdividing pastures and deferring grazing until a later date when pasture is in limited supply (such as stockpiling of grasses for summer or winter grazing); and providing supplemental feed on pastures during periods of low herbage supply. Subjectiveness which is mentioned as another disadvantage of P & T

technique is reduced if animals are adjusted on grazing pressure basis (requires an estimation of the amount of available forage) rather than based on visual appearance of sward. It is also possible in P & T method to estimate average stocking rate at various intervals of the grazing season to show the expected carrying capacity of different treatments throughout the grazing season and make practical recommendations to farmers as well. On the other hand, the complaint that fixed stocking does not define plant-animal interrelationships is only marginally true. The choice of several fixed stocking rates straddled about the optimum, could supply valuable information as to which rate yields the best animal performance or total product/ unit area on any particular treatment. This in itself is an excellent method of defining plant-animal systems for particular situations. Also when the available forage under the fixed stocking situation is monitored at the same intervals that animals are weighed, computation of grazing pressures associated with any level of animal performance is made possible. Subsequently, both the optimum stocking rate and grazing pressure are derived from the same experiment. Moreover, valid treatment comparisons are obtained by adjusting treatment effects on animal performance for differences in grazing pressures and/or stocking rates through covariance statistical analysis. It is only when a range of fixed stocking rates is adopted without any estimation of the available forage that most of the complaints against this method apply. Otherwise the choice between fixed and variable stocking could be based on the suggested criteria

listed by Wheeler et al. (1973). His suggested criteria were that the fixed stocking method is the more appropriate choice where: (1) the pattern of forage growth remains fairly uniform; (2) it is possible to maintain quality of forage if left uneaten; (3) minimum degree of flexibility available to accommodate forced or planned changes in animal numbers exists; (4) opportunity to modify animal response by management during trial is limited; (5) potential animal production of crop or total system can be reasonably well predicted at the design stage; (6) marketable animal product largely depends on the forage growth cycle; (7) the experimental result can be used later on a simple farm; (8) results are to be applied almost directly to a farming practice; and (9) the degree of disturbance to ecosystem acceptable is slight. The variable stocking rate is recommended for the contrary situation to the above options.

Management Systems of Grazing

Efficient forage utilization involves skillful management of all factors affecting the pasture-animal system. McMeekan (1960) suggested three basic factors which determine the conversion efficiency of pasture to animal products:

(1) The amount, quality and yield distribution of the pasture crop (pasture potential)

(2) The proportion of this crop harvested by the animal (grazing management)

(3) The efficiency of conversion within the animal of the fodder consumed (animal potential).

All three factors, however, operate concurrently to determine animal product per unit area as elaborated in the logistics of pasture evaluation by Mott and Moore (1970). In this part of the literature review we are mainly concerned with item (2).

According to Blaser et al. (1973), sound grazing management should be based on sound principles such as: (1) maintenance of desirable species or mixed association and botanical balance, (2) encouragement of rapid regrowth during and/or after grazing, (3) making wise compromises between yield and quality, and (4) minimizing costly operations. Consequently, grazing management generally implies adoption of one or the other of the different grazing systems namely (i) continuous and (ii) rotational. Rotational subsystems include (a) ordinary -- one group of animals, (b) two groups-- first and last grazers, (c) forward creep grazing, (d) strip or ration grazing and (e) stockpiling -- canopies accumulated for periods of sparse or no growth (Blaser et al., 1973).

Many reported experiments on management techniques provide little useful information because their designs neglected the facts that (a) a difference in stocking rate between the techniques under study will have an effect on production and thus confound the effect of the technique (Lucas and McMeekan, 1959; Line, 1970), and (b) comparisons at stocking rates far below the optimum are unlikely to test the techniques and are of little practical interest. Comparisons between grazing systems, made at uniform stocking rates, have shown little differences between strip, rotational, and continuous grazing (Campling, et al., 1958; Freer, 1959; Line, 1960). A general review

of the subject was made by Wheeler (1960) who concluded "contrary to frequently expressed opinion, forms of rotational grazing per se, have not, in objectively conducted experiments proved appreciably more productive (either in terms of product per animal or per unit land) than continuous grazing" (P. 68). In those experiments, strip grazing superiority over rotational grazing was only of the order of about 5%. In his review, Wheeler (1962) indicated that the rotational technique is useful for the preservation of good quality forage for feeding in physiologically critical periods, and the conservation of surplus material as hay or silage. McMeekan and Walshe (1963) reported that the optimum stocking rate under continuous grazing is reached at a level some 5 to 10% lower than the optimum rate applicable to controlled or rotational grazing. This means that rotational grazing must be associated with high stocking rates to exploit fully the greater efficiency of the more intensive grazing method. Conway (1965) tested the effects of grazing methods, stocking rates, feed restriction during winter, and hormones on the performance of beef cattle. Controlled and continuous grazing were compared at low, medium, and high rates of stocking. He found no difference in response to controlled grazing at the low and medium stocking rate, whereas, at high stocking rate, there was a highly significant response. It was then concluded that controlled grazing exhibits no advantage in terms of animal performance until high levels of stocking are reached and that stocking rate is of greater significance than methods of grazing. A similar finding was made by

Delgado and Alfonso (1974) who reported that gain per animal and gain per acre were affected by stocking rate but that a grazing rotational system using more than four paddocks was of little value in terms of animal performance.

Generally the superiority which rotational grazing holds over continuous grazing in terms of product per unit area is attributable to greater forage utilization and the key to achieving this is through adjustment of the stocking rate. Further, as discussed next, better forage yields could result from the alternating rest and harvesting schedule encountered with rotational rather than continuous grazing.

Effect of Stocking Rate and Grazing Management on Herbage Production

Experimental studies on the effect of stocking rate and management techniques on efficiency of animal production have been reviewed by McMeekan (1960), Wheeler (1960), Holmes (1962), and Humphreys (1966). These authors have discussed the results in relation to existing knowledge of the physiology of growth of mechanically defoliated herbage plants. Stocking rate has been shown to be an extremely potent factor on per unit area animal production through its effect on the efficiency of harvesting herbage. Fundamentally, production increased with increased stocking rates reflecting the greater proportion of the pasture that is harvested by the animal at the higher stocking rates. McMeekan (1961) showed that by increasing the stocking rate by 50%, the amount of digestible organic matter from each unit of land increased by 41%. Freer (1960) found that the mean utilization of available dry matter at stocking rates of 2.47 and 4.20 cows per hectare at each grazing of the rotational plots

increased from 30 to 74%, respectively. The amount eaten at each grazing at the higher stocking rate was equal to the amount that had grown since the previous grazing. Whereas at the lower stocking rate only 80% of this was eaten. However, although five times greater than the lower stocking rate, the mean rate of regrowth of the two swards was the same. Gordon et al. (1966) reported a similar result. Work on beef cattle grazing by Riewe et al. (1963) confirms that a significant reduction in herbage growth rates does not begin until a stocking rate higher than that which permits the maximum animal production per unit area is reached. All above workers examined temperate pastures and it is not known whether the same situation would prevail under tropical conditions.

The opinion is often expressed that high stocking rates are accompanied by major problems of rejection and waste of herbage by the grazing animal arising from contamination by feces. This subject has been reviewed by Barrow (1967) and Marsh and Campling (1970). While obvious rejection of dung contaminated areas occurs at low stocking rates, this becomes less pronounced as the grazing intensity increases. Greenhalgh and Reid (1968) in a study comparing the forage intake and production of dairy cows grazing dung-fouled herbage with those of cattle grazing clean herbage, showed that daily intake of digestible organic matter, milk yield, milk composition and live-weight gains were not significantly reduced by fouling. Marsh and Campling (1970) concluded in their review that: "If more emphasis were given to milk yield per hectare as an index of good grazing

management rather than to milk yield per cow or to sward appearance, it is probable that less importance would be attributed by pasture men to dung fouling" (P. 371).

Grazing management systems affect pasture plants in a number of ways such as total seasonal yield, longevity of species, botanical composition and physiological stage of growth; here, leaf area index, organic food reserves, location of meristematic tissue play very important roles as far as grazing management systems are concerned. Hence, differential response to defoliation and to various methods of grazing utilization are exhibited by different species (Blaser et al., 1962). The effect of various grazing management systems on herbage production was summarized by Blaser (1959). He pointed out that dry matter production was higher on rotational grazing than with continuous grazing and that larger species give the best yield responses to rotational grazing. He also mentioned that considering the growth physiology and morphology, forage production would be expected to increase from lower to higher value for utilization practices in the following order: (1) continuous grazing with constant stocking; (2) continuous grazing with controlled stocking; (3) rotational grazing with a narrow ratio of rest to grazing; (4) rotational grazing with a wide ratio of rest to grazing; (5) strip grazing; and (6) green soiling; and that the amount of available forage consumed follows a similar trend.

In both Puerto Rico and Hawaii, intensive forage production of tropical grasses declined considerably as measured by forage actually consumed by cattle compared with yield obtained from green chop (Rotar and Plucknett, 1973). This decline was attributed to waste by trampling and soiling by the grazing animal and to the uneven growth response of the forage after grazing.

MATERIALS AND METHODS

Experimental Design and Pasture Layout

The grazing experiment was conducted on 7.8 ha of a sandy, siliceous, hyperthermic family of Aeric Haplaquods (Immokalee series) located at the University of Florida Agricultural Research Center (ARC), Ona, Florida, during 1976 and 1977.

The three stargrasses studied were 'UF-5' (Cynodon aethiopicus Clayton and Harlan), 'UF-4' (Cynodon nlemfuensis Vanderyst.), and 'McCaleb' (Cynodon aethiopicus Clayton and Harlan). Three stocking rates were imposed on each stargrass forming a 3 x 3 factorial experiment. The stocking rates selected were 7.5 (low), 10 (medium) and 15 (high) cattle per hectare. The experiment was replicated over time (two years) rather than land area. 'Transvala' digitgrass (Digitaria decumbens Stent.) and 'Pensacola' bahiagrass (Paspalum notatum Flugge.) performance were also studied, with each containing one stocking rate (medium) over two replications.

The pasture layout is presented in Figure 1. An experimental unit consisted of three paddocks grazed in rotation (Table 1). The sizes of paddocks for the stargrasses were 0.26, 0.20, and 0.13 ha to obtain low, medium, and high stocking rates, respectively. Each paddock containing digitgrass or bahiagrass measured 0.20 ha since only the medium stocking rate was desired. Six cattle (three testers and three grazers) were allowed to start grazing in early June and

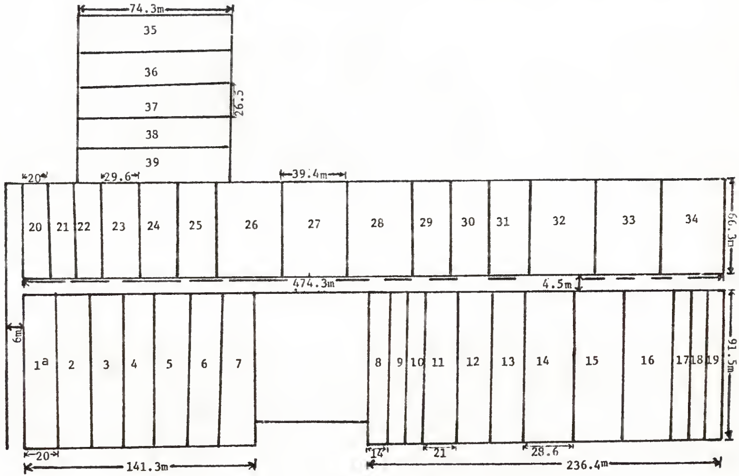

Figure 1. Field layout of pastures.

[a]Treatment assigned to subpastures is shown in Table 1.

Table 1. Treatment assignment to pastures.

Grass entry	Stocking Rate		
	High	Med	Low
	--Subpastures in rotational grazing----		
UF-5	20-21-22	23-24-25	26-27-28
UF-4	17-18-19	29-30-31	32-33-34
McCaleb	8 9-10	11-12-13	14-15-16
Digitgrass			
Replicate 1		1-2-3	
Replicate 2		35-36-37	
Bahiagrass			
Replicate 1		4-5-6	
Replicate 2		7-38-39	

maintained on each experimental unit until the onset of cool temperatures in the fall (late November) when some grazers were removed based on biweekly monitored animal performance.

Pasture Establishment and Management

The three stargrasses (UF-5, UF-4, and McCaleb) and the digitgrass were established vegetatively from stem-cuttings. Thirty-eight (36.4 kg) bales of fresh vegetative planting material were broadcast per hectare and disked into the surface (0 to 10 cm) of soil in June of 1975. Bahiagrass paddocks were seeded at the same time at a seeding rate of 33 kg/ha. Following establishment of all vegetatively planted grasses, 1.54 kg/ha 'Banvel' (dicamba -- 3,6-dichloro-o-anisic acid, manufactured by Velsicol Co.) were applied in 285 liters of water per hectare to control weeds (Cyperaceae and broadleaved weeds). The bahiagrass was not sprayed with dicamba but was clipped back to a 5 cm stubble twice to control weeds. Sixty days after planting the perennial grasses, 46.2 kg/ha N were applied to encourage species establishment. In December of 1975 and 1976, all established pastures received a uniform application of 0-44-88 kg/ha (N-P_2O_5-K_2O). A total of 220 kg/ha of N was applied in three split applications during each of the 1976 and 1977 growing seasons. All paddocks were fenced with electrified barbed wire and equipped with automatic watering equipment.

Percentage weeds in each paddock was visually estimated at the beginning and end of each grazing season. Broadleaf weeds were mechanically removed in 1976, but controlled with one spring

application of the herbicide Banvel (dicamba) at 1.32 kg/ha in 1977. Each paddock was staged once to a 15 cm stubble 28 days prior to commencement of grazing in 1976. Paddocks were not staged in the spring of 1977 allowing cattle to follow the grazing sequence established the previous year.

Cattle Management

The 1976 experiment was conducted using 78 yearling heifers averaging 250 kg across the following breeds: Brahman, Angus, Santa Gertrudis, and Charolais. In 1977, cattle of the above breeds averaged 230 kg at the initial weight.

Animals were equally divided on the basis of weight into groups of six each and randomly assigned to the experimental units for grazing in early June. Cattle were allowed to follow a schedule of 14 days grazing before being rotated to the next paddock. A 28-day rest period was allowed between grazing for grass regrowth. Grazing continued throughout the summer terminating in late November after four grazing cycles were completed (total of 168 days). Mineral supplement was provided *ad libitum* to cattle in each pasture throughout the grazing study. The manufacturer's guaranteed chemical analysis of the mineral supplement is presented in Appendix Table 1. Cattle were dewormed by treating with TBZ (43% Thiabendazole, Merck and Co. Inc.) in 1976 and 1977 and were routinely sprayed with CO-RAL (11.6% Coumaphos, Bayvet Corporation) for ectoparasites every six weeks, at time of weighing.

Field Measurements

Forage yield on the rotationally grazed pastures was estimated by the difference technique. Prior to and after grazing each paddock, three plots 3 x 0.8 m in size were randomly selected and harvested to a height of 7.5 cm for yield determination. Subsamples of about 200 g were removed from each harvest, dried, weighed, ground, and analysed for IVOMD and protein. The subsampling procedure conducted prior to each grazing necessitated the selection of green vegetative culms for accurate IVOMD and protein analysis.

Starting from the middle of July in both experimental years, sampling for total nonstructural carbohydrate (TNC) was conducted on each paddock, beginning on the first day of the grazing period and continuing weekly throughout the six-week grazing cycle. Only the 1976 TNC data will be reported in this manuscript. After sampling over a six-week period on all three paddocks within an experimental unit during the summer, TNC sampling was repeated in the fall season beginning in the middle of September. Six 10-cm core samples were randomly removed from each paddock to a rooting depth of 5 cm with a mechanical sod plugger and composited into two replicates of three cores each. Prior to sampling, the stubble height of each core was cut back to levels equal to the stubble height remaining after grazing for the appropriate grass and stocking rate combination as indicated in Table 2. Immediately following core sampling, all TNC samples were washed free of soil and debris, heated at 100°C for 60 minutes to denature respiratory enzymes and were subsequently dried at 60°C

Table 2. Grass stubble heights adopted for TNC core samples.

Stocking Rate	Grass				
	UF-5	UF-4	McCaleb	Digitgrass	Bahiagrass
	Stubble height, cm				
Low	17.5	25.0	22.0		
Med	15.0	20.0	22.5	17.5	12.5
High	12.0	12.5	17.5		

in a forced-draft oven. Dried tissue was separated into root and shoot components, ground to a 1 mm mesh fineness, sealed in plastic bags and stored in a freezer with a dessicant, in a large plastic bag prior to chemical analysis.

Following each six-week grazing cycle, cattle were weighed unshrunk in 1976 and shrunk 16 hours in 1977. A 4% estimate of body weight shrinkage was subtracted from all cattle weights in 1976 after each cycle. The average daily gains (ADG) measured during the grazing cycles were related to forage availability in defining plant-animal relationships.

Laboratory Determinations

Chemical analysis to estimate protein and IVOMD were conducted at the Forage Evaluation Laboratory at the University of Florida. The procedures employed involved the micro-Kjeldahl for N and the modified Tilley and Terry two-stage method (Moore et al., 1972) for IVOMD.

Extraction of TNC from dried, ground tissue followed the enzymatic procedure modified after Carter et al. (1973). Briefly, 0.1 g ground tissue was weighed into an Erlenmeyer flask and heated in boiling water bath with 5 ml deionized water for 10 minutes to gelatinize the starch. Five milliliters of 0.2 M acetate buffer, pH 4.8 then were added to bring the volume in the flask to 10 ml of 0.1 M acetate buffer.

One milliliter of the following enzyme mixture was removed while under constant stirring and used to digest the 0.1 g tissue in each flask. The enzyme mixture consisted of 1 ml invertase concentrate in glycerol; 0.80 g amyloglucosidase; 0.20 g takadiastase; 9.0 ml, 0.1 M, ph 4.8 acetate buffer; 5.0 ml, 80% ethyl alcohol solution with a few grains of thymol dissolved; and 30 ml of deionized water.

The thymol solution was included to prevent microbial growth during incubation. After enzyme addition, all samples were incubated at 41°C for 48 hours and then centrifuged at 15,000 rpm for 40 minutes, the supernatant liquid containing the TNC extract being decanted and immediately analyzed after the Nelson-Somogyi Copper reduction method (Nelson, 1944; Somogyi, 1945). Duplicate analyses were conducted on each field sample.

Calculations and Assumptions

The average growth rate of the pasture during the rest period was estimated by the formula:

$$\text{Growth rate} = \frac{B_i - A_{(i-1)}}{\text{R. P.}}$$

Where:

B_i = dry matter per hectare before grazing period i;

$A_{(i-1)}$ = dry matter per hectare after grazing period i-1;

R. P. = number of days of rest

The net dry matter production for a given cycle was calculated from net dry matter production/cycle (NP) =

$$B_i - A_{(i-1)} + \left[\frac{B_i - A_{(i-1)}}{R.\ P.} \times G.\ D.\right]$$

Where:

G. D. = grazing days

$$\text{Seasonal Dry Matter Yield} = \sum_{i-1}^{n} NP$$

Where:

n = number of grazing cycles for the season.

The total dry matter available for each grazing period was estimated by the equation:

Total available dry matter/cycle (TADM) =

$$B_i + \left[\frac{B_i - A_{(i-1)}}{R.\ P.} \times G.\ D.\right]$$

From the two equations (NP and TADM) it can be seen that the growth rate was assumed to be linear during a given rest period, as well as during the following grazing period.

Dry matter consumption per cycle was calculated from the formula:

Dry matter consumption/cycle =

$$\left[B_i + \left(\frac{B_i - A_{(i-1)}}{R.\ P.} \times G.\ D.\right)\right] - A_i = TADM - A_1$$

Where:

A_i = dry matter per hectare remaining after grazing period i.

In the calculation for consumption, no provision was made for the normal litter formation and decay.

The following is an example of how forage production was estimated for each grazing cycle:

Assume a residue of 3 kg DM/ha remained after previous grazing, 10 kg DM/ha was harvested after 28 days of rest period and the pasture was grazed for 14 days.

$$\text{Growth rate} = \frac{10 - 3}{28} = 0.25 \text{ kg DM/day}$$

$$NP = 10 - 3 + \frac{(10 - 3)}{28} \times 14$$

$$= 7 + 3.5 = 10.5 \text{ kg/ha.}$$

Seasonal DM yield = NP summed over all grazing cycles.

$$TADM = 10 + \frac{(10 - 3)}{28} \times 14$$

$$= 10 + 3.5 = 13.5 \text{ kg/ha}$$

Assume that residue of 4 kg DM/ha remained at the end of the current grazing cycle.

$$\text{DM consumption} = TADM - 4$$

$$= 13.5 - 4 = 9.5 \text{ kg DM/ha}$$

$$\text{Utilization} = \frac{9.5}{13.5} \times 100 = 70.4\%$$

RESULTS AND DISCUSSION

Net Dry Matter Production

Forage production of the stargrass pastures is presented in Tables 3 and 4, and the statistical analysis in Appendix Tables 3 and 4. Total seasonal yield for UF-5 stargrass varied from 22 metric tons/ha in 1976 to 16 metric tons/ha in 1977. A similar significant reduction from 19 to 16.5 metric tons/ha was measured on McCaleb stargrass between the two years. However, UF-4 stargrass produced an average total seasonal yield of 18.5 metric tons/ha for both 1976 and 1977. The moisture pattern in 1976 was more uniform than 1977 (Appendix Table 2). The yield reductions on UF-5 and McCaleb could have been due to the severe flooding that occurred during the summer of 1977 and this may explain the significant statistical variation between the two years as recorded in Appendix Table 4. Apparently, UF-4 may be more tolerant to saturated soil conditions or may by chance have been located on better drained plots.

Over 40% of the seasonal forage yield was produced in early summer. Forage production during a complete grazing cycle (six weeks) decreased markedly for all stargrass pastures during the fall season (cycle 4) especially in 1976 (Figure 2 and Table 3) because of low temperatures. Kawanabe (1968) reported a decrease of about 75% in the growth of warm-season grass species when the ambient temperature

Table 3. Net dry matter forage production of stargrasses as influenced by stocking rate during the 1976 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Seasonal total	Mean[a]
		Dates: 6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16		
		metric tons/ha					
UF-5	Low	10.04	6.72	1.00	2.58	20.34	5.09ab
	Med	8.46	5.26	4.57	2.75	21.04	5.26ab
	High	8.91	6.93	5.52	3.25	26.64	6.16a
	Submean	9.26	6.30	3.70	2.86	22.01	5.50A
UF-4	Low	8.58	3.56	1.79	0.03	13.96	3.49c
	Med	8.78	5.90	3.44	1.18	19.32	4.83ab
	High	9.62	7.10	4.69	1.78	23.20	5.80a
	Submean	8.99	5.52	3.31	1.00	18.83	4.71B
McCaleb	Low	8.17	6.10	2.62	0.39	17.28	4.32bc
	Med	8.57	6.45	3.58	2.25	20.88	5.22ab
	High	7.96	6.45	2.94	2.19	19.56	4.89ab
	Submean	8.23	6.33	3.05	1.61	19.24	4.81B
	Mean	8.78	6.05	3.35	1.82		

[a] Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 4. Net dry matter forage production of stargrasses as influenced by stocking rate during the 1977 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Seasonal total	Mean[a]
		Dates: 6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22		
		metric tons/ha					
UF-5	Low	6.73	3.18	2.57	3.04	15.52	3.83a
	Med	7.71	2.20	3.08	2.50	15.49	3.87a
	High	7.79	2.66	2.65	3.76	16.86	4.22a
	Submean	7.41	2.68	2.77	3.10	15.96	3.99A
UF-4	Low	8.09	3.27	3.31	3.72	18.39	4.60a
	Med	8.33	3.67	2.91	2.88	17.79	4.45a
	High	8.32	3.56	4.71	2.38	18.97	4.74a
	Submean	8.25	3.50	3.64	2.99	18.38	4.60A
McCaleb	Low	7.58	3.79	3.52	1.86	16.75	4.19a
	Med	7.76	3.70	2.69	1.35	15.50	3.88a
	High	7.21	4.69	2.78	2.63	17.31	4.33a
	Submean	7.52	4.06	3.00	1.95	16.52	4.13A
	Mean	7.73	3.41	3.14	2.68		

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

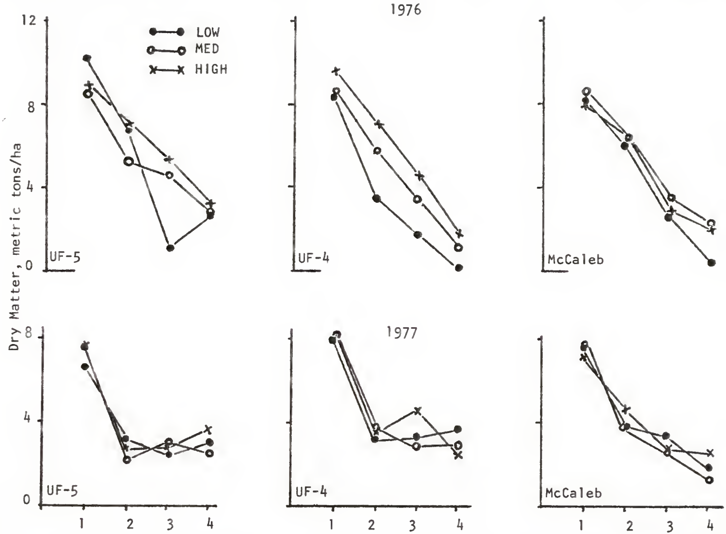

Figure 2. Distribution of net dry matter production for three stargrasses and three stocking rates during the 1976 and 1977 growing seasons.

was reduced from 36°C day/31°C night to 15/10°C. The mean monthly temperature at the Agricultural Research Center at Ona is compiled in Appendix Table 2.

Rate of stocking on pastures had a substantial impact on forage yield. The trend was toward a higher herbage production at the higher SR especially during the last two grazing cycles in 1976 (Table 3). This positive effect of stocking rate on yield was significant for UF-4 where the total seasonal forage production amounted to 14, 19, 23 metric tons/ha for the low, medium, and high SR, respectively (Table 3). Average net seasonal dry matter production for two years over all stargrasses were 17.0, 18.3, and 20.1 metric tons/ha for the low, medium, and high SR, respectively, which was statistically significant (Appendix Table 4).

Maraschin (1975) presented evidence that the yield of Coastcross-1 bermudagrass (Cynodon dactylon L.) under grazing, increased with increasing levels of residue left after grazing up to 2 metric tons/ha of residue and subsequently decreased as the accumulated residue reached 3 metric tons/ha. The amount of residue remaining after grazing in this study averaged over 5 metric tons/ha at the low SR in 1976 (Table 5). The accumulation of such high levels of standing residue may have possibly created a large metabolic sink for photosynthates, and also a shadding effect on new basal tillers, which could account for the negative yield response to decreased stocking in 1976. Amounts of residue were generally low in 1977 (Table 6) and no major differences in herbage yield could be attributed to the SR (Table 4).

Table 5. The effect of stocking rate on the amount of residue remaining after grazing in 1976.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	
		----Dates----				
		6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	Mean[a]
		----metric tons/ha----				
UF-5	Low	5.56	6.95	5.40	5.34	5.81a
	Med	4.00	3.88	3.44	3.93	3.81b
	High	2.97	2.47	1.63	1.47	2.14c
	Submean	4.18	4.43	3.49	3.58	3.92A
UF-4	Low	5.13	5.73	5.63	4.59	5.27a
	Med	4.08	4.65	4.89	3.90	4.38b
	High	2.93	3.03	2.29	1.40	2.41c
	Submean	4.05	4.47	4.27	3.30	4.02A
McCaleb	Low	4.27	5.82	5.69	4.65	5.11a
	Med	4.29	4.28	4.11	3.20	3.97b
	High	2.45	2.54	1.78	1.19	1.99c
	Submean	3.67	4.21	3.86	3.01	3.69A

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 6. The effect of stocking rate on the amount of residue remaining after grazing in 1977.

		Grazing cycle				
		1	2	3	4	
	Stocking	------------------Dates------------------				
Stargrass	rate	6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	Mean[a]
		---------------metric tons/ha---------------				
UF-5	Low	3.51	3.87	3.60	3.46	3.61a
	Med	4.14	3.37	2.89	2.04	3.11a
	High	3.88	1.92	1.15	0.96	1.98b
	Submean	3.84	3.05	2.55	2.15	2.90B
UF-4	Low	4.66	5.08	5.71	4.95	5.10a
	Med	4.12	3.76	3.16	2.31	3.34b
	High	3.63	1.70	0.95	0.93	3.41b
	Submean	4.14	3.51	3.27	2.73	3.41A
McCaleb	Low	4.81	4.26	3.71	2.17	3.74a
	Med	3.42	3.57	2.33	1.26	2.65b
	High	1.97	1.96	0.70	0.36	1.25c
	Submean	3.40	3.26	2.25	1.26	2.55B

[a]Means (within same grass variety), within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

UF-5 stargrass out-yielded UF-4 and McCaleb in 1976 only during the fourth grazing cycle (Table 3) when ambient temperatures were low. This cold tolerance characteristic of UF-5 stargrass also observed by Paul Mislevy* (personal communication) would require further investigation since it could enable the extension of the grazing season.

Total Available Dry Matter Per Unit Area

Much more forage was available to the grazing cattle during the early part of the growing season as compared with the available forage in the fall (Figure 3, Tables 7 and 8, Appendix Table 3). The higher dry matter production at the high SR (Tables 3 and 4) was insufficient to compensate for the greater utilization occurring for that treatment. Consequently, available forage on offer decreased linearly from low SR to high SR (Table 7, Appendix Table 3). However, a significant interaction between grass and SR in the above response was observed in 1976 (Appendix Table 3). The higher yield of UF-4 under the high SR was sufficient to offset increased utilization so that no differnce in total available forage occurred between the three SR (Table 7). This was not true for UF-5 and McCaleb stargrasses. In 1977, McCaleb was the only grass where the available forage decreased markedly as SR was increased, although this general trend also persisted for both UF-5 and UF-4 (Table 8).

The proportion of residue contained in the total available forage over all stargrass amounted to 64, 50, and 28% for the low, medium, and high SR, respectively, in 1976. The residue developed

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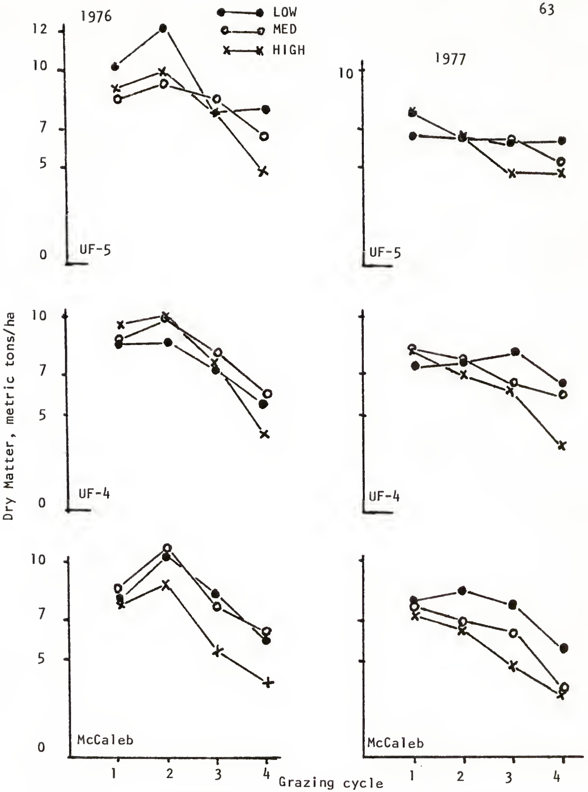

Figure 3. Distribution of total available forage for three star-grasses and three stocking rates within the 1976 and 1977 growing season.

Table 7. Total available dry matter of stargrass on offer as influenced by stocking rate during the 1976 grazing season.

		Grazing cycle				
		1	2	3	4	
	Stocking	Dates				
Stargrass	rate	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	Mean[a]
		metric tons/ha				
UF-5	Low	10.04	12.27	7.95	7.98	9.56a
	Med	8,46	9.25	8.45	6.19	8.09b
	High	8.90	9.89	7.98	4.87	7.91b
	Submean	9.13	10.47	8.13	6.35	8.52A
UF-4	Low	8.58	8.68	7.46	5.66	7.60a
	Med	8178	9.98	8.09	6.08	8.23a
	High	9.62	10.00	7.71	4.06	7.85a
	Submean	8.99	9.55	7.75	5.27	7.89A
McCaleb	Low	8.17	10.37	8.44	6.07	8.26a
	Med	8.57	10.74	7.85	6.36	8.38a
	High	7.96	8.90	5.50	3.97	6.58b
	Submean	8.23	10.00	7.26	5.47	7.74A
	Mean	8.79	10.01	7.71	5.69	

[a]Means (within same grass variety), within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 8. Total available dry matter of stargrass on offer as influenced by stocking rate during the 1977 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	
		Dates				
		6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	Mean[a]
		metric tons/ha				
UF-5	Low	6.73	6.68	6.43	6.63	6.62a
	Med	7.71	6.34	6.46	5.39	6.48a
	High	7.79	6.54	4.58	4.91	5.96a
	Submean	7.41	6.52	5.82	5.64	6.35A
UF-4	Low	8.09	7.94	8.38	6.76	7.69a
	Med	8.33	7.79	6.67	6.04	7.21a
	High	8.32	7.19	6.41	3.32	6.31a
	Submean	8.11	7.64	7.15	5.37	7.07A
McCaleb	Low	7.58	8.68	7.88	5.58	7.58a
	Med	7.76	7.00	6.32	3.67	6.19b
	High	7.21	6.65	4.74	3.33	5.48b
	Submean	7.72	7.44	6.31	4.19	6.36A
	Mean	7.75	7.20	6.43	5.06	

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

during the first cycle at the lower SR was carried over to the end of the season whereas, the level of residue at the high SR decreased during the season. The quality of residue and the possible effect it might have had on animal production is discussed in a later section.

Digestibility of Stargrass

The mean *in vitro* organic matter digestibility (IVOMD) of stargrass forage on offer for 1976 and 1977 ranged between 44 and 54% (Tables 9 and 10).

The IVOMD of the stargrasses showed a positive linear response ($P < .01$) to increasing SR in both experimental years (Tables 9, 10, and Appendix Table 5). As indicated earlier, closer grazing at the high SR reduced the proportion of residue after grazing and thus prompted new regrowth which tended to be more digestible. Homb (1953) and Maraschin (1975) made similar findings. The lower digestibility of forage found at the low SR might not, however, represent the animals' diet since selectivity would be higher under that treatment.

On the average, UF-5 was about three percentage units more digestible than UF-4 and McCaleb. Differences in IVOMD between the stargrasses may be explained on the basis of their morphology. UF-5 produces slender stems with an apparent high leaf-steam ratio. On the contrary, UF-4 produces numerous coarse stolons. McCaleb stargrass forms a moderately open sod with coarse erect stems as much as 5 mm in diameter and 50 to 70 cm in height (Hodges et al., 1975). Much of the culm base of McCaleb stargrass was refused by cattle because of its extreme coarseness.

Table 9. *In vitro* organic matter digestibility of stargrass forage on offer, at three stocking rates during 1976 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Mean[a]
		Dates 6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
		IVOMD, %				
UF-5	Low	46.70	48.78	45.79	42.57	45.96cd
	Med	50.35	49.44	46.42	48.91	48.78abc
	High	48.58	53.36	53.53	53.82	52.32a
	Submean	48.54	50.53	48.58	48.43	49.02A
UF-4	Low	41.72	48.79	42.36	43.40	44.07d
	Med	44.97	47.49	47.02	44.46	45.99bcd
	High	47.20	49.86	49.81	51.66	49.63ab
	Submean	44.63	48.71	46.40	46.51	46.56B
McCaleb	Low	47.13	44.59	42.05	43.06	44.21d
	Med	47.77	46.20	44.34	42.64	45.24cd
	High	49.99	50.06	45.05	47.60	49.11ab
	Submean	48.30	46.95	45.05	44.43	46.19B
	Mean	47.30	48.73	46.68	46.46	

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 10. *In vitro* organic matter digestibility of stargrass forage on offer, at three stocking rates during 1977 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Mean[a]
		Dates				
		6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	
		IVOMD, %				
UF-5	Low	48.84	53.71	52.81	51.03	51.60b
	Med	48.35	54.41	49.12	50.39	50.57bc
	High	49.79	57.29	55.25	55.07	54.37a
	Submean	48.99	55.14	52.39	52.16	52.17A
UF-4	Low	45.65	51.26	51.68	47.29	48.97bcd
	Med	44.50	50.24	49.72	46.46	47.73cd
	High	48.19	52.51	53.86	49.85	51.10b
	Submean	46.11	51.34	51.75	47.87	49.27B
McCaleb	Low	42.38	48.17	44.46	42.09	44.28e
	Med	44.15	50.52	48.97	43.89	46.88de
	High	44.72	54.76	49.55	48.57	49.40bcd
	Submean	43.75	51.15	47.66	44.85	46.85C
	Mean	46.28	52.54	50.60	48.29	

[a] Mean within the column followed by different letters are significantly different (P <.05) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

IVOMD of all stargrasses was highest immediately following N fertilization due to stimulation of new growth. These increases in digestibility are shown better in 1977 (Table 10) where the technique for selecting physiologically active samples was improved. Dates for N application are presented under the discussion on crude protein.

The quality of residue remaining after grazing was very low (Table 11). Digestibility of residual forage averaged between 33 and 35% on all stargrasses. There was a general trend towards a lower IVOMD of residue as SR was increased (Appendix Table 5) owing to the increased intensity of defoliation. The differences in residual IVOMD as affected by SR was significant only for McCaleb stargrass. IVOMD of residue was measured only during the 1976 grazing season.

Crude Protein

Crude protein content of all forage samples averaged about 9.9% which was about 1.5 percentage units higher than the critical level required to restrict forage intake (Tables 12 and 13). This critical level of crude protein content is estimated at between 6.0 and 8.5% (Blaxter and Wilson, 1963; Minson and Milford, 1967). The protein content showed a positive response ($P < .01$) to increased SR in 1976 (Table 12). In 1977, the response of crude protein to increasing SR was significant only during the last grazing cycle. Hence, the interaction between grazing cycle and stocking rate was significant for that year (Appendix Table 5).

Fertilizer N was broadcast in three split applications on 4/25, 7/18, 9/10 in 1976 and 3/31, 7/9, 9/13 during 1977. In a similar

Table 11. In vitro organic matter digestibility of stargrass residual material remaining after grazing at three stocking rates in 1976.

		Grazing cycle				
		1	2	3	4	
	Stocking	------------------Dates------------------				
Stargrass	rate	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	Mean[a]
		-------------------IVOMD, %-----------------------				
	Low	41.07	37.59	36.17	30.29	36.28a
UF-5	Med	37.82	38.234	34.47	31.50	35.53a
	High	37.17	34.23	33.15	32.58	34.28ab
	Submean	38.69	36.72	34.60	31.46	35.37A
	Low	35.75	36.34	34.19	30.15	34.11ab
UF-4	Med	37.38	36.54	34.65	29.31	34.47ab
	High	35.45	34.33	32.14	27.49	32.35b
	Submean	36.19	35.74	33.66	28.98	33.64B
	Low	38.71	37.11	34.48	31.60	35.48a
McCaleb	Med	37.86	35.84	33.96	30.13	34.45ab
	High	36.47	34.66	31.41	28.46	32.75b
	Submean	37.68	35.87	33.28	30.06	34.22AB

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 12. Crude protein content of stargrass forage on offer at three stocking rates during 1976 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Mean[a]
		Dates 6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
		CP, %				
UF-5	Low	8.66	8.18	8.18	9.61	8.66c
	Med	10.16	9.78	9.12	11.61	10.17ab
	High	8.87	11.61	10.51	13.21	11.05a
	Submean	9.23	9.86	9.27	11.48	9.96A
UF-4	Low	8.79	8.79	8.92	10.91	9.35bc
	Med	9.15	8.24	9.85	10.01	9.31bc
	High	10.10	9.92	10.47	11.20	10.42ab
	Submean	9.35	8.98	9.75	10.71	9.69A
McCaleb	Low	10.39	8.31	8.87	9.53	9.28bc
	Med	10.52	9.31	9.76	9.80	9.85abc
	High	11.80	10.46	10.61	11.42	11.07a
	Submean	10.90	9.36	9.75	10.25	10.07A
	Mean	9.83	9.40	9.59	10.81	

[a]Means within the column followed by different letters are significantly different (P <.05) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 13. Crude protein content of stargrass forage on offer at three stocking rates during 1977 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Mean[a]
		Dates 6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	
		CP, %				
UF-5	Low	11.40	12.64	10.81	9.86	11.02a
	Med	10.61	13.01	9.97	10.08	10.92a
	High	8.69	12.73	10.70	11.11	10.82a
	Submean	10.23	12.79	10.28	10.35	10.92A
UF-4	Low	8.51	11.35	9.78	9.08	9.68a
	Med	7.77	11.18	8.90	9.86	9.43a
	High	7.68	11.50	10.50	12.32	10.50a
	Submean	7.99	11.34	9.73	10.42	9.87A
McCaleb	Low	8.42	10.39	9.93	8.85	9.40a
	Med	8.69	11.75	9.63	9.37	9.86a
	High	8.76	13.77	10.68	11.97	11.30a
	Submean	8.62	11.97	10.08	10.06	10.19A
	Mean	8.95	12.03	10.03	10.28	

[a]Means within the column followed by different letters are significantly different (P <.05) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

trend to digestibility, protein content was highest soon after N application in 1977 but not in 1976. The difference between the years was attributed to improvement in sampling technique to include only physiologically active material during the second experimental year. The positive linear relationship existing between digestibility and crude protein is well documented by other workers (Minson et al., 1964; Wilkinson et al., 1970). It is also very likely that the values of crude protein presented did not simulate the animals diet expecially at the low SR because of higher diet selectivity.

All three stargrasses were very similar in protein content in each experimental year. The principal factors controlling protein content in tropical grasses as reviewed in the literature are maturity and N fertilization. These factors were applied evenly to all varieties, and the similarity was expected.

Crude protein content of residue (Table 14) fell within the critical range established in the literature. The highest average level of crude protein measured on the residues amounted to 7%.

Forage Utilization and Stocking Rate

The proportion of grazeable forage on offer harvested by cattle is presented in Tables 15 and 16. The available forage utilized during a grazing cycle, averaged over all stargrasses was 34.1, 49.1, and 70.7% for the low, medium, and high SR, respectively, in 1976 (Table 15). Utilization of total available dry matter during 1977 grazing season amounted to 41.8, 52.7, and 71.6% for low, medium, and high SR,

Table 14. Crude protein content of stargrass residual material remaining after grazing at three stocking rates in 1976.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	
		Dates				
		6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	Mean[a]
		CP, %				
UF-5	Low	6.67	4.40	4.55	7.13	6.69a
	Med	6.66	7.18	7.36	8.18	7.05a
	High	7.26	5.70	7.21	8.01	7.05a
	Submean	6.86	6.42	7.04	7.77	7.03A
UF-4	Low	6.86	6.50	6.68	6.15	6.55a
	Med	6.85	7.21	7.63	6.63	7.08a
	High	6.58	6.58	6.91	5.85	6.48a
	Submean	6.76	6.76	7.07	6.21	6.70A
McCaleb	Low	6.80	7.29	6.52	6.69	6.83a
	Med	7.43	6.91	7.01	6.74	7.02a
	High	7.59	7.36	7.16	6.94	7.26a
	Submean	7.27	7.19	6.90	6.79	7.04A

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 15. Utilization of stargrass forage on offer as influenced by stocking rate during 1976 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Mean[a]
		--------Dates--------				
		6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
		------Utilization of total available DM, %-------				
	Low	44.8	43.4	31.1	32.3	37.9c
UF-5	Med	51.2	58.6	55.8	36.0	50.4b
	High	67.1	76.0	80.7	70.9	73.7a
	Submean	54.4	59.3	55.9	46.4	54.0A
	Low	38.5	34.1	23.9	15.2	27.9d
UF-4	Med	52.5	53.2	38.8	36.2	45.2bc
	High	68.4	70.1	70.8	67.2	69.1a
	Submean	53.1	52.5	44.5	39.5	47.46B
	Low	47.3	43.8	32.2	22.9	36.6cd
McCaleb	Med	49.5	60.2	47.8	49.5	51.8b
	High	69.0	71.9	66.2	70.6	69.4a
	Submean	55.3	58.6	48.7	47.7	52.6A
	Mean	54.3	56.8	49.7	44.5	

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

Table 16. Utilization of stargrass forage on offer as influenced by stocking rate during the 1977 grazing season.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	
		--------Dates--------				
		6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	Mean[a]
		-----Utilization of Total Available DM, %-------				
UF-5	Low	45.9	36.8	44.1	42.6	42.4cd
	Med	43.8	41.8	55.1	62.1	50.7bc
	High	48.9	63.6	74.8	79.3	66.7a
	Submean	46.2	47.4	58.0	61.3	53.3B
UF-4	Low	38.7	32.7	30.8	27.3	32.4d
	Med	45.2	43.2	53.1	61.9	50.9bc
	High	55.5	73.4	85.7	71.4	71.5a
	Submean	46.5	49.8	56.5	53.5	51.6B
McCaleb	Low	43.0	46.4	52.6	60.4	50.6bc
	Med	53.0	42.7	63.4	66.4	56.4b
	High	68.9	65.8	85.5	90.3	77.6a
	Submean	55.0	51.6	67.2	62.4	61.5A
	Mean	49.2	49.6	60.6	62.4	

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test. Means of SR are compared with lowercase letters whereas means of grass varieties are compared with uppercase letters.

respectively (Table 16). The linear increase in forage consumption effected by increased SR was significant at $P < .01$ for both years (Appendix Table 3). The above values are in agreement with the findings of Freer (1960) who reported that the percentage utilization of available dry matter on rotationally grazed plots increased from 30 to 74% at SR of 2.47 and 4.20 cows per hectare, respectively. McMeekan (1961) also demonstrated that by increasing the SR by 50%, the amount of digestible organic matter harvested per unit area of land increased by 41%. In effect, stocking rate is a tool for improving the efficiency of harvesting herbage if manipulated wisely. However, increased utilization does not necessarily imply more intake per animal. On the contrary, because selective grazing by cattle tends to become limited as the efficiency of utilization is improved, the compromise between greater utilization and preservation of diet quality provides the crux of grazing management.

In 1976, a marked decrease in percentage utilization of available forage was observed at the lower SR as the season progressed whereas consumption either increased or stabilized at the high SR (Table 15). The decreased consumption as the season progressed on the low SR might have been due to the increased proportion of low quality residual matter in the total diet. Consequently, the interaction between SR and grazing cycle was significant for that year (Appendix Table 3).

In 1977, forage yield on UF-5 and McCaleb pastures was relatively low resulting in smaller accumulation of residue. Utilization of

these two stargrass varieties, therefore, increased toward the end of the season on all treatments as animals were forced to graze the small amount of forage available (Table 16). In Table 17 and Appendix Table 4, utilization was computed and analyzed on the basis of seasonal net dry matter production rather than the total available dry matter during a grazing cycle. For the two-year period, utilization of net dry matter averaged 75% at low SR, 86% at medium SR, and 95% at high SR (Table 17).

Forage intake (kg DM consumed/animal/day) decreased by increasing the SR. For example, the average daily intake at the low, medium, and high SR over all stargrasses and experimental years was 10.2, 9.3, and 7.6 kg DM/head/day, respectively (Table 17).

Comparison of Forage Production on all Five Entries of Grasses at Medium Stocking Rate

Net dry matter forage production averaged 20 metric tons/ha on the stargrasses, 15 on digitgrass, and 10 on bahiagrass (Table 18) at the medium SR in 1976. Yield estimates were made to 7.5 cm height of cut; hence, the value for bahiagrass especially might have been underestimated, since it is a low-growing grass. Forage yield in 1977 also was higher on the stargrasses (Table 18, Appendix Table 6). Total available forage during a grazing cycle was also much greater on the stargrasses when compared with either digitgrass or bahiagrass (Table 19).

UF-4 and McCaleb stargrass were of lower digestibility than digitgrass (Table 20 and Appendix Table 6), but UF-5 had IVOMD

Table 17. The effect of three stocking rates on the utilization and intake of seasonal[a] forage production of stargrass.

Stocking Rate	Stargrass	Seasonal yield	Residue[b]	Consumption	Utilization	Intake
		--------metric tons/ha------			---%--	kg,DM/head/day
	UF-5	17.93	4.40	13.53	76	10.8
Low	UF-4	16.18	4.77	11.41	70	9.1
	McCaleb	17.01	3.41	13.61	80	10.8
	Submean[c]	17.04b	4.19	12.85c	75.3c	10.2a
	UF-5	18.27	2.99	15.28	84	9.1
Med	UF-4	18.56	3.11	15.45	84	9.2
	McCaleb	18.19	2.23	15.96	89	9.5
	Submean	18.34ab	2.78b	15.56b	85.7b	9.3a
	UF-5	20.75	1.22	19.54	94	7.8
High	UF-4	21.09	1.17	19.92	95	8.0
	McCaleb	18.44	0.78	17.66	96	7.0
	Submean	20.09a	1.06c	19.04a	95.0a	7.6b

[a]Mean values of two years seasonal data.

[b]Residue at end of season.

[c]Submeans within the column followed by different letters are significantly different (P <.05) according to Duncan's Multiple Range Test.

Table 18. Net dry matter production of five tropical grass entries at the medium stocking rate for 1976 and 1977.

Grass entry	Grazing cycle 1	2	3	4	Total	Mean[a]
	1976 Dates					
	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16		
	metric tons/ha					
UF-5	8.46	5.26	4.57	2.75	21.04	5.26a
UF-4	8.78	5.90	3.44	1.18	19.32	4.83ab
McCaleb	8.57	6.45	3.58	2.25	20.85	5.21a
Bahiagass	5.02	3.33	0.81	0.71	9.87	2.47c
Digitgrass	8.15	4.07	2.66	0.00	14.88	3.72b
	1977 Dates					
	6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22		
	metric tons/ha					
UF-5	7.71	2.20	3.08	2.50	15.99	3.87a
UF-4	8.33	3.67	2.91	2.88	17.79	4.45a
McCaleb	7.76	3.70	2.69	1.34	15.49	3.87a
Bahiagrass	4.79	1.00	1.24	1.30	8.33	2.08b

[a]Means within the column and year followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test.

Table 19. Total available forage of five tropical grass entries at the medium stocking rate for 1976 and 1977.

Grass entry	Grazing cycle 1	2	3	4	Mean[a]
	1976 Dates				
	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	metric tons/ha				
UF-5	8.46	9.25	8.45	6.19	8.09a
UF-4	8.78	9.78	8.09	6.08	8.18a
McCaleb	8.57	10.74	7.85	6.36	8.38a
Bahiagrass	5.02	5.24	2.58	1.57	3.60c
Digitgrass	8.15	8.16	5.50	2.07	5.97b
	1976 Dates				
	6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	
	metric tons/ha				
UF-5	7.71	6.34	6.46	5.39	6.48a
UF-4	8.33	7.79	6.67	6.04	7.21a
McCaleb	7.76	7.00	6.32	3.67	6.19a
Bahiagrass	4.79	3.65	2.30	1.74	3.12b

[a]Means within the column and year followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test.

Table 20. *In vitro* organic matter digestion of forage on offer for five tropical grass entries at the medium stocking rate for 1976 and 1977.

Grass entry	Grazing cycle 1	2	3	4	Mean[a]
	1976 Dates				
	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	IVOMD, %				
UF-5	50.35	49.44	46.42	48.91	48.78ab
UF-4	44.97	47.49	47.02	44.46	45.99bc
McCaleb	47.77	46.20	44.34	42.64	45.24c
Bahiagrass	46.94	44.63	47.22	46.61	46.35bc
Digitgrass	51.95	50.67	50.49	50.90	51.00a
	1977 Dates				
	6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	
	IVOMD, %				
UF-5	48.35	54.41	49.12	50.39	50.57a
UF-4	44.50	50.24	49.72	46.45	47.73ab
McCaleb	44.15	50.52	48.97	43.89	46.88b
Bahiagrass	48.05	47.40	54.22	50.98	50.16a

[a]Means within the column and year followed by different letters are significantly different (P < .05) according to Duncan's Multiple Range Test.

comparable to digitgrass. The IVOMD of bahiagrass varied significantly between the two years, but on the average there was little difference in the quality of bahiagrass as compared with the stargrasses. All five entries of tropical grasses exhibited a similar crude protein content at the medium SR, averaging about 9.9% (Table 21). Nitrogen fertilizer was applied uniformly to all pastures and the similarity in crude protein was expected.

With forage quality of all grasses being about equal, the lower total available dry matter on digitgrass and bahiagrass was partially compensated for by higher utilization during each grazing cycle at the medium SR when compared with the stargrasses (Table 22). For the 1976 grazing season, forage dry matter of stargrasses consumed at medium SR averaged 16.7 metric tons/ha (Table 23). Practically all the seasonal forage produced from digitgrass and bahiagrass (14.4 and 9.6 metric tons/ha, respectively) was consumed by end of the season. Vincente- Chandler et al. (1974) estimated that stargrass in Puerto Rico produced between 2-3 metric tons more forage (in terms of consumption) than did pangola digitgrass. The quality of residue on all five grasses was equally poor (Table 24).

Effect of Stocking Rate on Animal Production

Average daily gains of the cattle during individual experimental years are shown in Appendix Tables 7 and 8. The seasonal average daily gains of all tester animals over the two years were regressed on stocking rate for the different stargrass varieties, and the derived equations of best fit are plotted in Figure 4.

Table 21. Crude protein content of five tropical grass entries at the medium stocking rate for 1976 and 1977.

Grass entry	Grazing cycle 1	2	3	4	Mean[a]
	1976 Dates				
	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	CP, %				
UF-5	10.16	9.78	9.12	11.61	10.17a
UF-4	9.15	8.24	9.85	10.01	9.31a
McCaleb	10.52	9.31	9.76	9.80	9.85a
Bahiagrass	9.00	9.16	10.84	11.79	10.20a
Digitgrass	7.91	8.51	9.71	13.46	9.90a
	1977 Dates				
	6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	
	CP, %				
UF-5	10.61	13.01	9.97	10.08	10.92ab
UF-4	7.77	11.18	8.90	9.86	9.43b
McCaleb	8.69	11.75	9.63	9.37	9.86b
Bahiagrass	9.26	11.56	11.84	12.04	11.18a

[a]Means within the column and year followed by different letters are significantly different (P < .05) according to Duncan's Multiple Range Test.

Table 22. Forage utilization of five tropical grass entries at the medium stocking rate for 1976 and 1977.

Grass entry	Grazing cycle 1	2	3	4	Mean[a]
	1976 Dates				
	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	utilization of total available DM, %				
UF-5	51.16	58.56	55.76	36.01	50.37b
UF-4	52.53	53.21	38.31	36.20	45.19b
McCaleb	49.54	60.22	47.76	49.52	51.76b
Bahiagrass	63.18	65.93	69.30	83.13	70.39a
Digitgrass	44.81	66.18	62.59	75.71	62.32a
	1977 Dates				
	6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	
	utilization of total available DM, %				
UF-5	43.8	41.8	55.1	62.1	50.70b
UF-4	45.23	43.20	53.10	61.87	50.85b
McCaleb	53.03	42.73	63.43	66.43	56.41b
Bahiagrass	45.27	73.18	83.13	94.03	73.90a

[a]Means within the column and year followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test.

Table 23. Seasonal[a] forage yield and utiliation of five tropical grass entries at medium stocking rate in 1976.

Grass entry	Seasonal yield	Residue[b]	Consumption	Utilization	Intake
	----------metric tons/ha---------			-----%----	kg DM/head/day
UF-5	21.04a	3.39	17.11a	81	10.2
UF-4	19.32a	3.90	15.42a	80	9.2
McCaleb	20.88a	3.20	17.68a	85	10.5
Digitgrass	14.88b	0.50	14.38a	97	8.6
Bahiagrass	9.87c	0.26	9.61b	97	5.7

[a]Values within the column followed by different letters are significantly different (P <.05) according to Duncan's Multiple Range Test.

[b]Residue at end of season.

Table 24. Quality of residue of five tropical grass entries at the medium stocking rate in 1976.

Grass Entry	Grazing cycle 1	2	3	4	
	Dates 6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	Mean[a]
	IVOMD, %				
UF-5	37.8	38.3	34.5	31.5	35.5a
UF-4	37.4	36.5	34.6	29.3	34.5a
McCaleb	37.9	35.8	34.0	30.1	34.4a
Digitgrass	38.7	35.2	32.7	32.6	35.0a
Bahiagrass	39.4	35.1	35.8	35.6	36.7a
	CP, %				
UF-5	6.66	7.18	7.36	8.18	7.35b
UF-4	6.86	7.21	7.63	6.63	7.08b
McCaleb	7.43	6.92	7.01	6.74	7.02b
Digitgrass	5.73	6.99	8.09	9.39	7.55ab
Bahiagrass	7.01	7.69	8.68	8.89	8.07a

[a]Means within the column followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test.

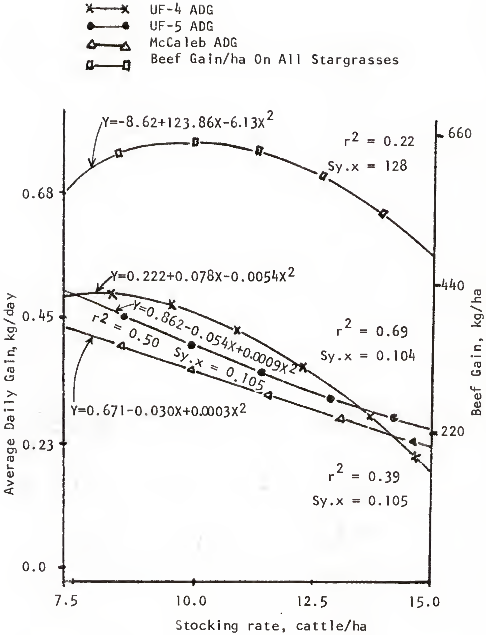

Figure 4. Relationships between average daily gain, gain/ha and stocking rate on stargrasses.

The regression analysis indicated that SR had a significant effect on cattle average daily gain ($P < .01$). Gain/animal/day increased as SR decreased.

A test of the deviation of the data from linearity was not significant on UF-5 and McCaleb indicating that the decrease in average daily gains as affected by increased SR was linear on those grasses (Appendix Table 9). In the case of UF-4, when ADG was regressed on SR, the quadratic function was quite high ($P < .10$, Appendix Table 9 and Figure 4). Support for both the linear model (Jones and Sandland, 1974) and the quadratic model (Riewe, 1967; Hart, 1972) occurs in the literature. On the other hand, Connolly (1975) cautioned that in order to fit a quadratic relationship to mean gains, four or more SR are necessary to give a good estimate of error and consequently any discriminatory test between linear and quadratic models especially where there is no herd replication. In this study, only three experimental SR were considered and even the low SR was quite high for maximizing average daily gain. Hence, there was a tendency for the three points to become linearized as demonstrated by Connolly (1975). Consequently the derivation of the optimum SR (Mott, 1960) from Figure 4 becomes difficult except in the case of UF-4 where the optimum seems to fall near the low SR.

Cummulative average liveweight changes of cattle and cattle grazing days/ha of all treatments are compiled in Appendix Tables 10 to 13. Total liveweight gain (kg/ha/168 days) data are presented in Table 25. The 4% estimated shrinkage subtracted from 1976

Table 25. Beef produced per unit area of land from stargrass as influenced by stocking rate.

Stargrass	Stocking rate	Grazing season 1976	Grazing season 1977	Mean
	-Cattle/ha-	kg/ha		
	7.5	568	686 → 21%	627
UF-5	10.0	612	670 → 9%	641
	15.0	594	630 → 6%	612
	Submean	591	662	627
	7.5	521	625 → 20%	573
UF-4	10.0	557	763 → 37%	660
	15.0	119	561 → 471%	340
	Submean	399	650	524
	7.5	453	600 → 32%	527
McCaleb	10.0	572	528 → -8%	550
	15.0	426	490 → 15%	458
	Submean	484	539	512
	Mean	491	617	

liveweight gain data might have been too high and this could explain the lower production occurring that year. Other reasons for better cattle performance in 1977 might be the more uniform distribution of forage yield and the lower initial weight of cattle used for grazing that season. Cattle gain per hectare averaged over two years on the stargrasses were 470 kg/ha, 617 and 576 at the high, medium, and low SR repectively. The above response of gain per hectare to SR fitted a quadratic model ($P < .16$) which is plotted in Figure 4. This result is in perfect agreement with Jones and Sandland (1974) who derived a quadratic relation between gain per unit area and stocking rate. The coefficient of determination ($r^2 = 0.22$) was very low because of the large variations in cattle gains between the two years. From Figure 4 the optimum stocking rate evaluated on the basis of maximum cattle gain/ha seems to be located near the medium SR (10 cattle/ha). When the beef production (kg/ha/168 days) was extrapolated to the equivalent gain that would occur on a yearly basis, the estimated liveweight gains (940 to 1234 kg/ha) compared favorably with those reported for stargrass (1400 kg/ha) by Vincente-Chandler et al. (1974) in Puerto Rico where year-round temperatures are more ideal for the growth of warm-season grasses.

Relationship Between Cattle Production and Forage Measurements

Cattle average daily gains shown in Appendix Tables 7 and 8 were related to the total available and residual dry matter at a grazing cycle, each expressed both as metric tons/ha and kg DM/100 kg BW/day.

The two expressions (total available and residual DM on kg DM/100 kg BW/day) are indicative of grazing pressure. Estimated grazing pressures on the basis of total available dry matter are tabulated (Appendix Table 14 and 15). Regression equations for all tropical grass entries relating ADG to forage parameters were derived and are presented in Table 26.

Generally higher coefficients of determination (r^2) were found between ADG and forage parameters than with SR, confirming the primary importance of forage estimation in grazing trials.

Relationships between ADG and forage parameters expressed as metric tons/ha were largely linear while the relationship with grazing pressure was exponential. The fact that ADG shows a linear response to available dry matter (metric tons/ha) has been reported for warm season perennial grasses by Duble et al. (1971) and Salazar-Diaz (1977). The idea that the relationship between animal gain and grazing pressure is exponential was developed by Vohnout and Jimenez (1975) who described the relationship in the form $Y = A + Be^{-CX}$

where Y = ADG, X = grazing pressure, A, B, and C are constants.

Total Available DM and Residue (metric tons/ha)

Linear regression equations between ADG and available forage per hectare are in Table 26. There was much similarity in the regression equations for the grass entries. These data showed that a minimum of between 3 and 4 metric tons/ha available dry matter across all SR was required to maintain cattle weight on stargrasses

Table 26. Relationship between average daily gain (kg) per cattle (Y) and forage parameters (X).

Parameter[b]	Regression[a]	Sy.x	r^2	P
Forage measurements Metric tons/ha				
(a) Total available;				
(i) UF-5	Y=-0.452+0.136X	0.141	0.49	.0108
(ii) UF-4	Y=-0.525+0.132X	0.170	0.58	.0038
(iii) McCaleb	Y=-0.544+0.143X	0.163	0.71	.0006
(iv) Digitgrass	Y=-0.391+0.112X	0.148	0.84	.0014
(v) Bahiagrass	Y=-0.241+0.173X	0.135	0.77	.0042
(b) Residue;				
(i) UF-5	Y=-0.036+0.155X	0.085	0.82	.0001
(ii) UF-4	Y=0.035+0.112X	0.195	0.54	.0065
(iii) McCaleb	Y=-0.035+0.157X	0.194	0.59	.0035
(iv) Digitgrass	Y=-0.180+0.189X	0.202	0.70	.0100
(v) Bahiagrass	Y=0.044+0.237X	0.074	0.93	.0001
Grazing pressure kg DM/100 kg BW/day:				
(A) Total available;				
(a) Exponential				
(i) UF-5	$Y=0.6390-1.4466e^{(-0.3445X)}$	0.131	0.61	.005
(ii) UF-4	$Y=0.6115-2.9037e^{(-0.35059X)}$	0.149	0.78	.005

Table 26 - Continued

Parameter[b]	Regression[a]	Sy.x	r^2	P
(iii) McCaleb	$Y=0.6718-1.5465e^{(-0.3020X)}$	0.207	0.44	.005
(b) Two-stage				
(i) UF-5	$Y=0.5439$			
	$Y=-0.2989+0.1349X$	0.117	0.69	.005
	where $X < 6.25$			
(ii) UF-4	$Y=0.4559$			
	$Y=-1.0296+0.2223X$	0.143	0.80	.005
	where $X < 6.68$			
(iii) McCaleb	$Y=0.5683$			
	$Y=-0.1802+0.0967X$	0.206	0.56	.01
	where $X < 7.74$			
(B) Residue				
(i) UF-5	$Y=0.6188-0.7376e^{(-0.5678X)}$	0.102	0.76	.005
(ii) UF-4	$Y=0.5711-0.9962e^{(-1.001X)}$	0.157	0.65	.005
(iii) McCaleb	$Y=0.9328-0.9223e^{(-0.2143X)}$	0.229	0.49	.005
(iv) Digitgrass	$Y=0.8748-1.2519e^{(-0.4174X)}$	0.203	0.74	.005
(v) Bahiagrass	$Y=0.3038-2.3531e^{(-8.9878X)}$	0.184	0.53	.025

[a]Equations for stargrasses based on 12 pairs of observations and those for digitgrass based on 8 pairs of observations.

[b]On dry matter basis.

and digitgrass during the six-week grazing cycle. The value was somewhat lower for bahiagrass (about 2 metric tons).

The minimum amount of residue at the end of grazing required for cattle maintenance averaged 0.2 metric tons/ha on stargrasses and bahiagrass and about 1 metric ton/ha on digitgrass (Table 26). Regression of ADG on residue gave a better fit on UF-5 ($r^2 = 0.82$) and bahiagrass ($r^2 = 0.93$), whereas regression on total available forage produced a better model for UF-4 ($r^2 = 0.58$, McCaleb ($r^2 = 0.58$), and Transvala ($r^2 = 0.84$). Comparatively, UF-5 and especially bahiagrass are low growing and since harvest was made to 7.5 cm height of cut, yield of forage that occurred below this level was not accounted for in relating total available forage to ADG. On the contrary, the yield of UF-4, McCaleb, and digitgrass was concentrated more above 7.5 cm which explains the better fit of ADG on total available forage for those three grass entries.

Grazing Pressures (kg DM/100 kg Animal BW/day)

When gain/cattle/day was regressed on kg forage available or residue per 100 kg of cattle body weight, the relationship appeared to be linear up to the point where maximum average daily gain was reached. Beyond this point further increases in available forage did not include much response in animal performance. Vounhnout and Jimenez (1975) proposed that the relationship between ADG and grazing pressure was of the form $Y - A + Be^{-CX}$. The fitted exponential model is summarized in Table 26. Exponential equations using kg

total available DM/100 kg BW/day could not be developed for digit-grass and bahiagrass because the range of estimated grazing pressures was generally below the level required for maximum average daily gain (Appendix Table 16).

Petersen et al. (1965) reported that ADG was a positive linear function of forage availability to the point of maximum intake. Using the nonlinear least squares regression analysis to fit a two-stage curve between ADG and kg total available forage/100 kg BW (Petersen et al., 1965) resulted in a slightly better fit than the exponential model (compare r^2 values in Table 26). The general form of the two-stage curve and the values of constants estimated for the stargrasses are also summarized in Table 26.

On UF-5, average daily gain showed a positive linear response ($P < .005$) to the increase in grazing pressure up to the level of 6.25 (two-stage in Table 26 and Figure 5). Corresponding values for UF-4 and McCaleb were 6.68 and 7.74, respectively (Table 26, Figures 6 and 7). The higher value estimated for McCaleb might have been due to the fact that most of the coarse erect basal stems were refused. Maximum average daily gains associated with the grazing pressures indicated above were estimated at 0.54 kg/day on UF-5, 0.46 kg/day on UF-4, and 0.57 kg/day on McCaleb (Figures 5, 6 and 7). Maximum ADG of about 0.60 kg/day is generally accepted as near the maximum rate of steer gains from grazing trials conducted on tropical grasses (Salazar-Diaz, 1977). Hence, maximum

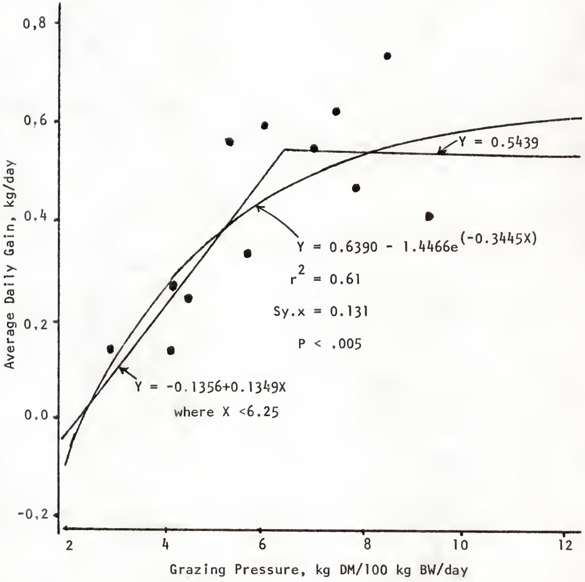

Figure 5. Relationship between average daily gain and grazing pressure on UF-5 stargrass.

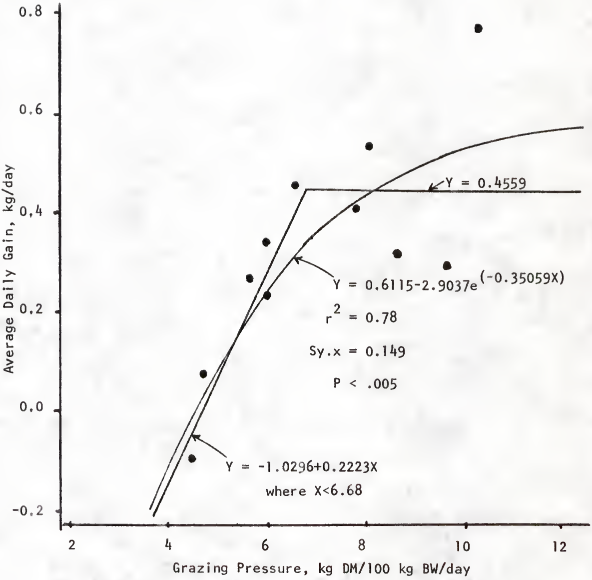

Figure 6. Relationship between average daily gain and grazing pressure on UF-4 stargrass.

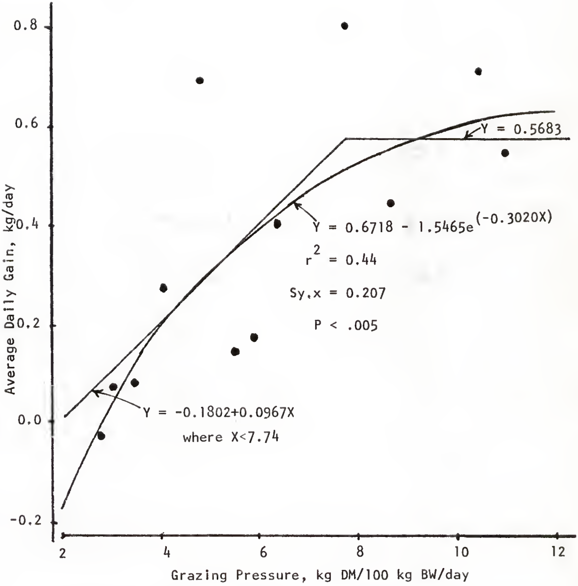

Figure 7. Relationship between average daily gain and grazing pressure on McCaleb stargrass.

average daily cattle gain on the stargrasses was obtained with a minimum of between 6 and 7 kg of total available forage/100 kg animal body weight/day. In a similar study of Pangola digitgrass, Salazar-Diaz (1977) reported the optimum grazing pressure to fall between 5.5 and 7 kg DM/100 kg BW/day.

This optimum range of grazing pressure (6 to 7) came nearest to the mean grazing pressure estimated for the medium stocking rate (Appendid Tables 14 and 15). However, at the beginning of the growing season when forage growth was very rapid the optimum grazing pressure (6 to 7) occurred only when using the high stocking rate. The high standard deviation estimated for the regression equations probably is due to variance associated with forage availability measures and also the fact that forage availability measures do not include depression in gain resulting from quality changes.

Comparison of ADG and Beef Product Per Unit Area on Five Entries of Tropical Grasses

The average daily cattle gains on the five entries of tropical grasses (Table 27) adjusted for differences in grazing pressure were compared. The estimated grazing pressures are shown in Appendix Table 16 and the result of the covariance analysis (Appendix Table 17) did not indicate any significant differences in ADG. The adjusted mean daily gains are shown plotted against grazing pressure in Figure 8. The statistical analysis suggest that the quality of the five tropical grasses (as determined by ADG) was not different

Table 27. Average daily gain by cattle on five tropical grass entries at the medium stocking rate.

Grass Entry	Grazing cycle 1	2	3	4	Mean[a]
	----1976 Dates----				
	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	----kg/day----				
UF-5	0.55	0.20	0.38	0.36	0.37a
UF-4	0.52	0.31	0.46	0.07	0.34a
McCaleb	0.39	0.64	0.36	0.02	0.35a
Bahiagrass	0.39	0.25	0.20	0.01	0.22a
Digitgrass	0.60	0.53	0.08	0.10	0.28a
	----1977 Dates----				
	6/7-7/19	7/19-8/30	8/30-10/11	10/5-11/16	
	----kg/day----				
UF-5	0.47	0.59	0.32	0.24	0.41a
UF-4	0.75	0.58	0.37	0.26	0.49a
McCaleb	0.80	0.40	0.14	0.08	0.36a
Bahiagrass	0.70	0.23	0.15	0.10	0.30a

[a]Means within the column and year followed by different letters are significantly different ($P < .05$) according to Duncan's Multiple Range Test.

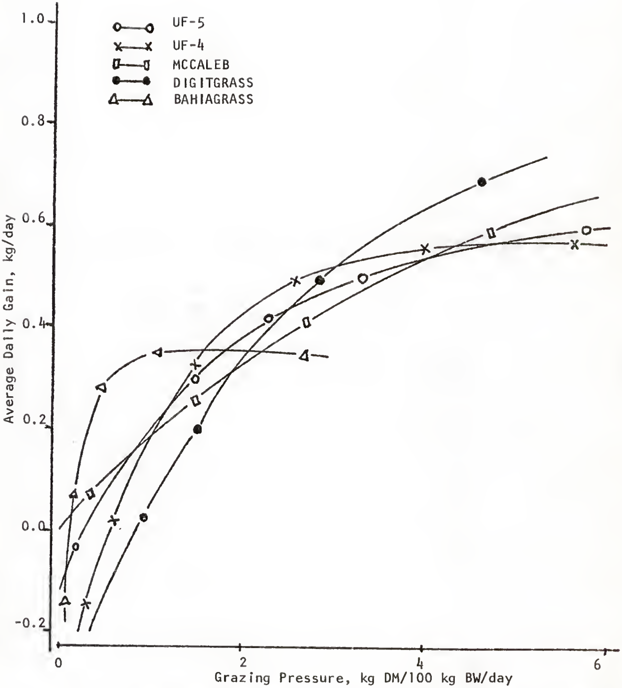

Figure 8. Relationship between average daily gain and residual grazing pressure on five tropical grass entries.

and that the observed differences measured in ADG between the grass entries were due primarily to differences in grazing pressure (Appendix Table 17).

The interaction ($P < .10$) between grazing pressure and grass entry indicates that bahiagrass was superior to the other grasses at low levels of residue but inferior when the amount of residue surpassed the 2 kg/100 kg BW margin (Figure 8). For the stargrasses, the plot of ADG against the exponentials of residue/100 kg BW was very similar to that against total available dry matter/100 kg BW. On the basis of residual grazing pressure maximum cattle gains (0.58 kg/day) is obtained with a minimum daily accumulation of 2.5 kg residue/100 kg BW.

The amount of beef produced from unit area of land for the five grasses is summarized in Table 28. In 1976 the pooled error mean square of SR against stargrass analysis and digitgrass against bahiagrass, on the other hand, was used to test the effect of grass entry on beef product/ha (explained in Appendix Table 18). As a result of higher grazing days on the stargrasses at the medium SR, marked differences in total liveweight gain were realized when compared with beef product per hectare on digitgrass and bahiagrass. This kind of statistical evaluation could not be made in 1977 because the digitgrass was eliminated from the study.

Physiological Response of Five Tropical Grass Entries to Grazing

The rate of recovery and total yield of a defoliated plant, although dependent to a large extent upon external environmental

Table 28. Beef produced per unit area of land from five tropical grass entries at the medium stocking rate.

Grass entry	Grazing season 1976	1977
	----Beef product[a],kg/ha----	
UF-5	612a	670
UF-4	557ab	763
McCaleb	572a	528
Digitgrass	461b	---
Bahiagrass	396b	418

[a]Values within the column followed by different letters are significantly different (P < .05) according to Duncan's Multiple Range Test.

factors, are also influenced considerably by the remaining leaf area and organic food reserves present in the tissue of the stubble and roots. The accumulation of carbohydrate reserves in plant tissue is a dynamic system of energy balance between photosynthesis and respiration. Grazing management practices, such as season of use, degree of utilization and grazing systems, are partially based upon how they affect carbohydrate reserves of grasses. According to the National Research Council (1962), the effects of management practices on plant vigor are measured objectively and quantitatively with percentage of total nonstructural carbohydrate (TNC). In the following sections, the variation of TNC, monitored during a grazing cycle and season for the individual tropical grass entries, is discussed.

Total Nonstructural Carbohydrate (TNC) Content in Stubble and Roots of UF-5 Stargrass

The amount of carbohydrate reserves measured for all treatments is summarized in Appendix Tables 19 and 20, and analyses of variance are shown in Appendix Tables 21 and 22. Carbohydrate reserves in both stubble and roots of UF-5 stargrass exhibited much variation following defoliation by grazing (Figure 9, Appendix Table 21). This response of TNC to defoliation monitored at weekly intervals, from the beginning of grazing to the end of a grazing cycle fitted a quadratic model on all treatments ($P < .01$). The data indicated a substantial drop of TNC during the two-week grazing period (Figure 9)

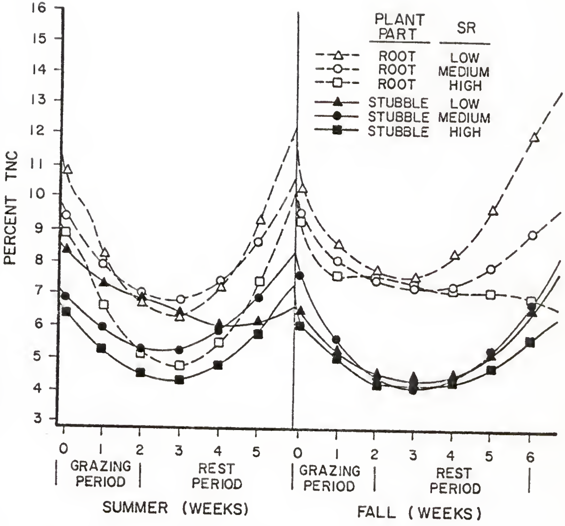

Figure 9. Total nonstructural carbohydrate found in the stubble and roots of UF-5 stargrass during a summer and fall grazing cycle following three stocking rates.

reaching the lowest level in the first week of regrowth (between two and three weeks, Figure 9). This finding is supported by the evidence of Jameson (1963) who reported that in many grass species the reserve level is lowest when the second or third leaf emerges. Enough photosynthetic leaf area was generated after two weeks' rest period to enable resoration of depleted TCN to proceed. Both the rate of decrease of TNC during grazing and the rate of recovery during rest period proceeded at a much faster rate as SR was reduced. The faster recovery could be attributed to the greater leaf area and the higher organic reserves remaining in the defoliated stubble following the more lenient grazing. Also it is expected that more ungrazed tillers would remain at low SR. The four-week rest period was sufficient to enable full recovery of lost TNC at all treatments on UF-5.

On the average, there was no significant difference in TNC levels between summer and fall seasons (Appendix Table 21). However, significant interaction ($P < .01$) was observed between the two seasons and plant parts. Root TNC showed a greater response to grazing during summer than fall. In the fall season, possibly due to cooler temperatures and shorter day lengths, a greater partitioning of photosynthates into the roots occurred, resulting in a much greater difference between stem and root carbohydrate levels.

Throughout the entire growing season, significantly higher concentrations of TNC were maintained in the roots than the top growth ($P < .01$) and at lower SR on UF-5 stargrass (Figures 10 and 11). The only variance to the above observation was that no difference

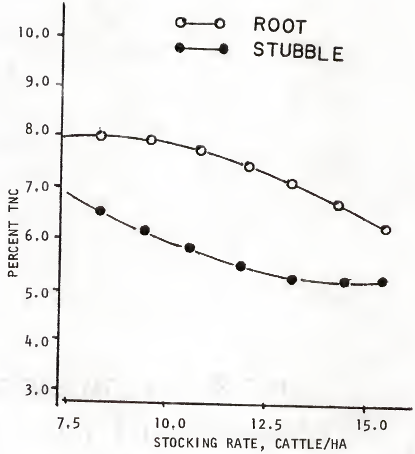

Figure 10. The effect of stocking rate on total non-structural carbohydrate in the stubble and roots of UF-5 stargrass during summer.

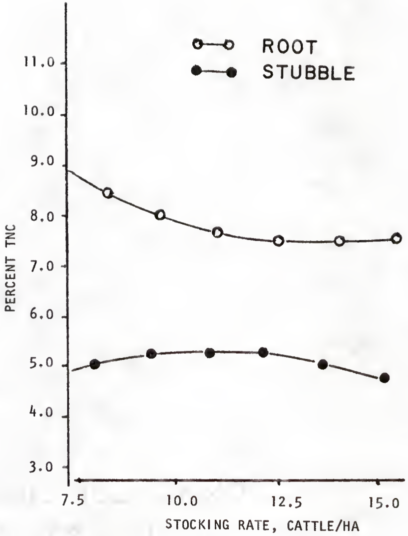

Figure 11. The effect of stocking rate on total non-structural carbohydrate in the stubble and roots of UF-5 stargrass during fall.

due to SR was observed for topgrowth TNC during the fall season (Figure 11). The highest content of TNC (10% on DM basis) was measured in the roots at the end of the rest period under low SR and the minimum level of 4.5% was estimated in the topgrowth stubble during the first week of regrowth under high SR (Figure 9).

For the greater part of the growing season, TNC content in the roots did not decrease below 7% as compared with 4.5% in the topgrowth.

Total Nonstructural Carbohydrate (TNC) Content in Stubble and Roots of UF-4 Stargrass

The amount of organic reserves stored in the roots of UF-4 stargras was much higher than that stored in the stem ($P < .01$).

The decrease in TNC during grazing was reversed by the end of the first week of rest regrowth period (Figure 12). The recovery rate of TNC occurred at a much faster rate at the low SR.

TNC in UF-4 was subject to much less fluctuation in the summer grazing cycle than the fall season. Hence, the interaction between seasons and weeks from beginning of grazing was significant (Appendix Table 21). In the fall season, a greater degree of partitioning of photosynthates into the underground parts was observed. This resulted in a significant interaction between season and plant part (Appendix Table 21). The outcome was that in the fall season, roots maintained or increased their summer levels of TNC at the expense of the stubble (Figure 12).

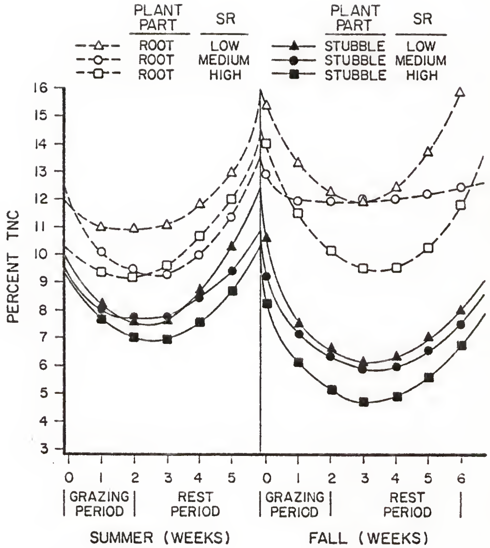

Figure 12, Total nonstructural carbohydrate found in the stubble and roots of UF-4 stargrass during a summer and fall grazing cycle following three stocking rates.

Stocking rate produced a greater effect on root rather than stubble carbohydrate and in fall rather than summer. For example, there was no difference in stem carbohydrate attributable to SR during summer (Figure 13) whereas, in the fall both root and stubble carbohydrate showed a marked linear reduction ($P < .01$) at high SR (Figure 14).

The highest level of TNC determined for UF-4 (14.9%) was measured in the roots during the fall season at low SR. The corresponding figure for the stubble (9.9%) was obtained in summer at low SR. Minimum root TNC level was 7.5% which occurred during summer on high SR. The same treatment produced the lowest level of TNC measured in the stem (4.1%) in the fall.

Total Nonstructural Carbohydrate (TNC) Content in Stubble and Roots of McCaleb Stargrass

The striking similarity between McCaleb stargrass (Figure 15) and UF-5 stargrass (Figure 9) in their TNC response to defoliation confirms once more their common speciation. Similar to UF-5, both stubble and root reserve carbohydrate, especially under medium and high SR, demonstrated a greater degree of mobility in the summer compared to fall season and there was a greater partitioning of carbohydrates into the roots in the fall. The root TNC content at the low SR did not vary in summer probably because an adequate amount of vegetative tillers remained to keep TNC high.

Averaged over all SR and plant parts, a much greater ($P < .01$) TNC content was measured during fall as compared to summer on McCaleb

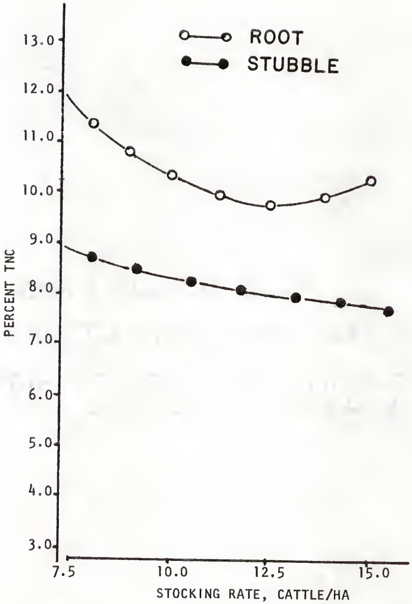

Figure 13. The effect of stocking rate on total non-structural carbohydrate in the stubble and roots of UF-4 stargrass during summer.

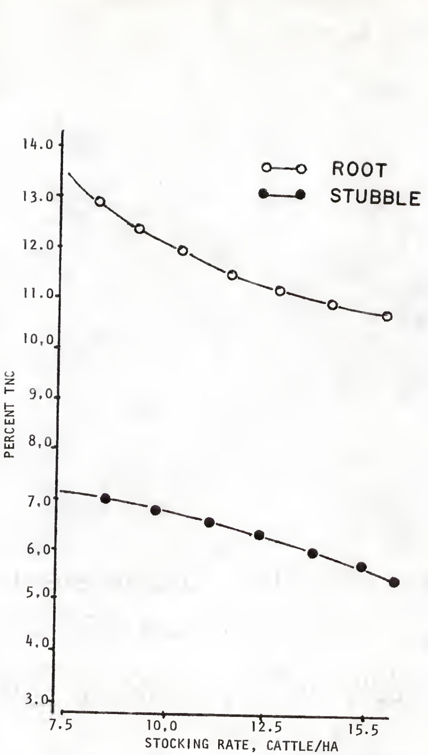

Figure 14. The effect of stocking rate on total non-structural carbohydrate in the stubble and roots of UF-4 stargrass during fall.

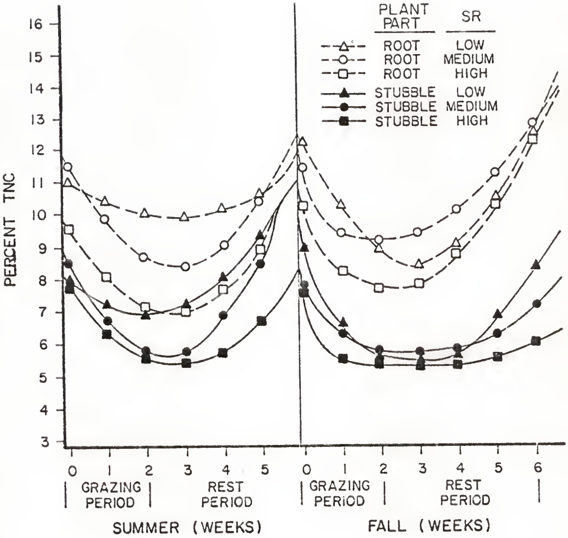

Figure 15. Total nonstructural carbohydrate found in the stubble and roots of McCaleb stargrass during a summer and fall grazing cycle following three stocking rates.

stargrass and roots contained higher TNC than the stubble (Appendix Table 21).

Increasing the SR slowed down the rate of carbohydrate recovery. Consequently, TNC in both stubble and roots decreased ($P < .01$) with increasing SR during the two grazing cycles as shown in Figures 16 and 17. Minimum summer-root TNC content at the high SR amounted to 6.8% of DM. The minimum fall stubble TNC was estimated at about 4.5% which was the same level that occurred in the summer. UF-5 stubble under the high SR also reached equally low TNC levels during summer and fall - another similarity between the two entries. The behavior of UF-4 in this regard was different because the minimum fall-stubble TNC (4.1%) was lower than the minimum summer TNC (5.4%).

Total Nonstructural Carbohydrate (TNC) Content in Stubble and Roots of Transvala Digitgrass

Distribution of TNC in digitgrass differed greatly from that in the stargrass. Except towards the end of the season, TNC content in the stubble was markedly higher than that found in the roots (Figure 18 and Appendix Table 22).

The response of digitgrass root TNC to grazing was minimal compared with that of the stubble. This was also at variance with root TNC response for the stargrasses.

In the summer grazing cycle, the decrease in organic reserves during grazing was completely recovered by the end of the 28-day rest period. A dramatic reduction in stubble carbohydrate occurred during grazing in the fall and plants were not able to replenish this

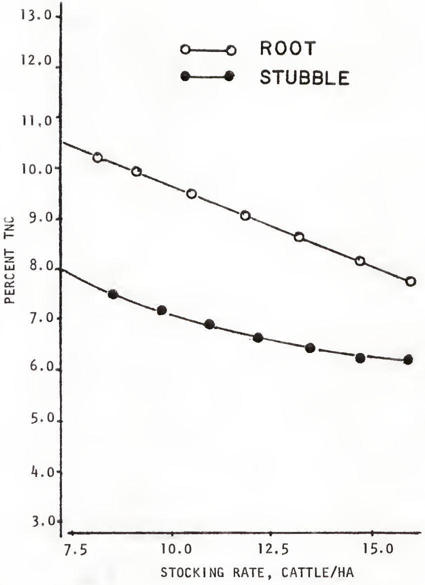

Figure 16. The effect of stocking rate on total non-structural carbohydrate in the stubble and roots of McCaleb stargrass during summer.

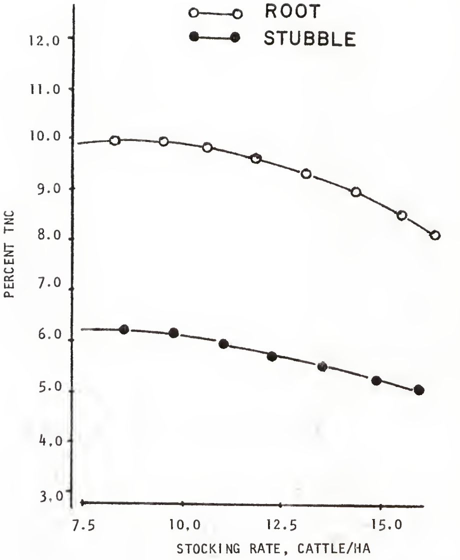

Figure 17. The effect of stocking rate on total nonstructural carbohydrate in the stubble and roots of McCaleb stargrass during fall.

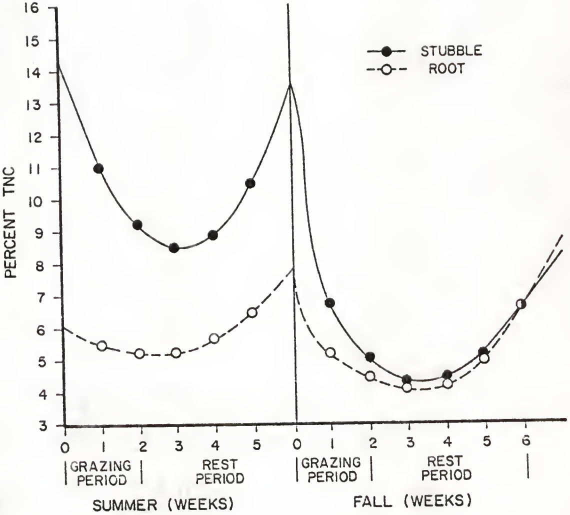

Figure 18. Total nonstructural carbohydrate in the stubble and roots of Transvala digitgrass during a summer and fall grazing cycle at the medium stocking rate.

depletion during the rest period. The physiological basis of reduced photosynthetic rates by digitgrass during cool season is well documented (West, 1971; Boyd, et al., 1973). When digitgrass is subjected to cool nights (10°C), starch particles remain in the chloroplasts due to inactivation of the hydrolytic enzyme α-amylase. Subsequent photosynthesis causes more starch to accumulate until the chloroplast particle is ruptured. The injury to the chloroplast as a result of continued accumulation of starch in the leaf reduces photosynthetic rates. The combined effect of severe grazing and cool temperatures in the fall consequently reduced TNC levels in the crown of digitgrass to extremely low levels (3.5%) and plants were unable to recover.

Total Nonstructural Carbohydrate (TNC) Content in Stubble and Roots of Bahiagrass

Larger quantities of organic food reserves were stored in the stubble (rhizomes) of bahiagrass than the roots (Figure 19). This type of distribution was similar to that of digitgrass and contrary to the situation in the stargrass. Bahiagrass also had the highest level of TNC of all the five tropical grass entries studied. In summer, the rhizomes contained about 23% TNC following the rest period and the lowest amount estimated in the stubble (rhizome) during fall season was 13%. Grazing influenced TNC in the stubble more than roots.

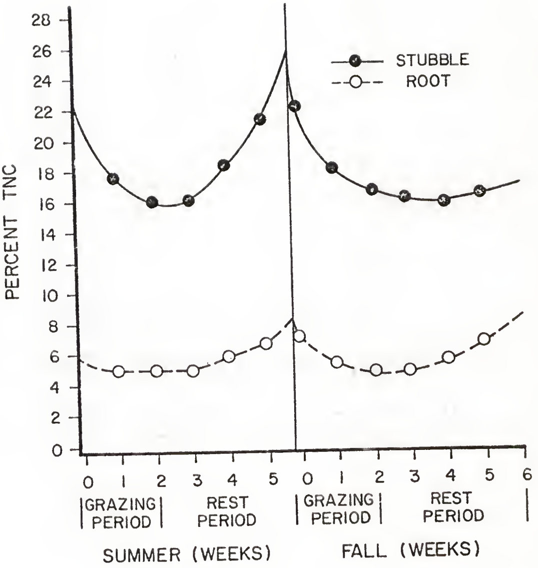

Figure 19. Total nonstructural carbohydrate in the stubble and roots of Pensacola bahiagrass during a summer and fall grazing cycle at the medium stocking rate.

Botanical Composition of Pastures

There was an indication that low levels of TNC in the stubble of the grasses at the end of a growing season resulted in weakened plants thus encouraging weed infestation (Table 29). For example, Transvala digitgrass got so heavily infested with common bermudagrass that grazing had to be abandoned on that grass during the second grazing year. Similarly UF-4 at the high SR and to some extent McCaleb stargrass with the same treatment experienced a substantial increase in weed population.

The increased weed percentage at the low SR on UF-5 probably was due to the incidence of spittlebug attack during the fall season of 1976. Spittlebug attacks are known to occur commonly at Ona in grass stubble with dense growth and an accumulation of dead plant litter on the soil surface (Hodges et al., 1975).

Pensacola bahiagrass showed the greatest resistance to weed infestation.

Table 29. Botanical composition of pastures of five tropical grass entries.

Grass entry	Stocking rate	Grazing season Beginning 1976	End 1976	End 1977
		---Weed infestation, % of sward--		
	Low	0.5	0.5	12.3
UF-5	Med	0.2	0.2	1.0
	High	0.0	0.2	0.0
	Low	13.3	26	4.0
UF-4	Med	11.0	14	6.0
	High	14.0	21	42.0
	Low	0.8	0.0	0.0
McCaleb	Med	0.3	0.3	0.0
	High	1.0	0.5	2.3
Digitgrass	Med			
	Replicate 1	0.5	35	80
	Replicate 2	0.2	20	65
Bahiagrass	Med			
	Replicate 1	0.5	0.0	0.3
	Replicate 2	0.7	0.5	0.2

SUMMARY AND CONCLUSIONS

Grazing trials were conducted at the University of Florida Agricultural Research Center, Ona, Florida, during 1976 and 1977 growing seasons, to study the effects of three stocking rates (SR) (7.5, low; 10, medium; 15 cattle/ha, high) and the associated grazing pressures on the yield, quality, forage utilization, carbohydrate reserves, and cattle performance on three African stargrasses called UF-5 and McCaleb (*Cynodon aethiopicus* Clayton and Harlan) and UF-4 (*Cynodon nlemfuensis* Vanderyst.). In addition, the medium SR was imposed on Transvala digitgrass (*Digitaria decumbens* Stent.) and Pensacola bahiagrass (*Paspalum notatum* Flugge).

The grazing experiment was conducted on 7.8 ha of a sandy, siliceous hyperthermic family of Aeric Haplaquods (Immokalee series). The stargrasses and digitgrass were established from stem-cuttings (at 1400 kg fresh vegetative planting material/ha), whereas, the bahiagrass was established from seed (at seeding rate of 33 kg/ha). Pastures were fertilized with one uniform application of 0-44-88 kg/ha (N-P_2O_5-K_2O) and a total of 200 kg/ha N in three split applications annually. Each treatment was assigned an experimental unit that consisted of three subpastures grazed in rotation. The size of subpastures was varied between 0.26, 0.20, and 0.13 ha to obtain low, medium, and high SR, respectively.

Grazing was effected with 78 yearling heifers averaging about 240 kg at the initial weight, across the breeds; Brahman, Angus, Santa Gertrudis, and Charolais. The animals, equally divided on the basis of weight into groups of six each, were randomly assigned to the experimental units for grazing in early June. Cattle were allowed to follow a schedule of 14 days grazing before being rotated to the next paddock after a 28-day regrowth period.

Forage dry matter yields and consumption were measured for each six-week grazing cycle by randomly selecting and harvesting three 3 X 0.8 m plots prior to and after grazing each subpasture. Subsamples of green vegetative culms were selected from each harvest for IVOMD and crude protein analysis. From the middle of July, sampling for total nonstructural carbohydrate (TNC) was conducted on each subpasture, beginning on the first day of the grazing cycle and continuing weekly throughout the six-week grazing cycle. TNC sampling was repeated in the fall season, beginning in the middle of September. Cattle were weighed at the end of each six-week grazing cycle.

From the results obtained, the following conclusions could be drawn:

Seasonal forage net dry matter production on the stargrasses increased from 17 to 20 metric tons/ha as SR was increased from low to high. However, the amount of forage available for grazing during each grazing cycle was inversely related to SR and there was an interaction between grass and SR in the above response.

Utilization of both the total available forage during a grazing cycle and the seasonal dry matter yield increased markedly from low to high SR, but intake at the high SR (7.6 kg DM/cattle/day) was lower compared with those at the lenient grazing pressures (9.3 and 10.2 for the medium and low SR, respectively). Stargrasses produced much more forage (in terms of consumption) than either digitgrass or bahiagrass at the medium SR.

The IVOMD of stargrass forage on offer was very sensitive to SR, increasing from 44 to 54% as SR was increased. This was an indirect effect mediated by the higher proportion of low quality residue remaining at the low SR. The IVOMD of digitgrass (51%) was very similar to that of UF-5 stargrass but superior to those of UF-4 and McCaleb stargrasses and bahiagrass. Forage from all five tropical grass entries contained about the same level of crude protein (9.9%).

Total nonstructural carbohydrate (TNC) reserves in grass stubble and roots showed a marked quadratic response to grazing. The TNC levels decreased significantly during the two weeks' grazing period, reached a minimal level at the end of the first week of rest period then increased throughout the remaining of the rest period. A re-growth (rest period) of 28 days was sufficient to recover fully, the depleted TNC on all treatments, with the exception of digitgrass in the fall season. In stargrasses, the concentration of TNC in the roots was higher than that in the stubble. However, TNC was greater in the stubble than in the roots of digitgrass, and higher

in the rhizomes than roots of bahiagrass. The minimum TNC levels observed in both the roots (6 to 8% on DM basis) and the stubble (4 to 5%) of stargrasses were obtained at the high SR. Bahiagrass rhizomes contained the highest level of TNC (23%).

Cattle average daily gains (ADG) on stargrasses varied from 0.18 to 0.56 kg/day. The ADG showed an inverse-linear relationship to SR, a linear function to available forage or residue (metric tons/ha) and a nonlinear function to grazing pressure (kg DM/100 kg BW/day). The minimum grazing pressure required to obtain maximum ADG on stargrass ranged from 6 to 7 kg available DM/100 kg BW/day or the accumulation of 2 to 4 kg residue/100 kg BW/day based on varietal differences. Beef gain per hectare averaged over two years for stargrasses, varied from 470 kg/ha at the high, 617 at the medium, to 576 at the low SR.

Average daily gains over all stargrasses at the medium SR in 1976 was 0.35 kg/day as compared with 0.28 on digitgrass and 0.22 on bahiagrass. Although these rates of gain were not statistically different, they created marked differences in total beef gain/ha which averaged 580 kg/ha on stargrasses, 461 on digitgrasses, and 369 on bahiagrasses, all measured at the medium SR in 1976.

APPENDIX

Appendix Table 1. Manufacture's[a] guaranteed analysis of mineral supplement.

Ca	$\geq$	12.0%
P	$\leq$	12.0%
NaCl	$\geq$	25.0%
Fe	$\geq$	1.0%
Cu	$\geq$	0.13%
Co	$\geq$	0.03%
Mn	$\geq$	0.05%
Zn	$\geq$	0.10%
F	$\leq$	0.18%
Total mineral ingredients		
90.0%, Vit. A 200.00 U.S.P. Units/lb		

[a]Manufactured by Lakeland Cash Feed Co., Lakeland, Florida.

Appendix Table 2. Monthly mean, maximum and minimum temperatures and rainfall at the Agricultural Research Center, Ona, Florida, during 1976 and 1977.

	Rainfall			Temperature					
	34 Years'			1976			1977		
Month	Ave	1976	1977	Max	Min	Ave	Max	Min	Ave
	---------cm---------			------------------°C------------------					
Jan.	4.98	2.48	4.48	21.8	6.7	14.3	17.9	5.0	11.5
Feb.	6.15	1.05	3.35	24.6	9.5	17.1	22.1	7.3	14.7
Mar.	6.98	0.80	2.93	28.5	12.7	20.6	27.6	13.8	20.7
Apr.	6.20	3.98	0.70	28.8	12.4	20.6	28.9	12.9	20.9
May	9.80	14.98	9.33	29.9	17.9	23.9	30.6	15.9	23.2
June	21.85	18.58	11.05	31.0	19.3	25.2	32.9	20.1	26.5
July	23.25	13.05	27.06	32.5	20.7	26.6	32.9	20.6	26.8
Aug.	20.40	13.06	28.45	32.2	21.1	26.7	32.2	21.9	27.1
Sep.	18.35	10.15	24.13	31.7	20.1	25.9	30.2	21.8	26.1
Oct.	8.68	6.13	1.90	27.6	15.7	21.7	27.9	15.8	21.9
Nov.	4.50	5.13	7.08	24.4	11.8	18.1	26.3	13.4	19.9
Dec.	4.30	4.63	7.25	21.0	9.3	15.2	21.7	9.8	15.8

Appendix Table 3. Analysis of variance for forage measurements of stargrasses during the grazing cycles.

		Dry matter production							
		Net		Total available		Residue		Utilization	
Source	df	1976	1977	1976	1977	1976	1977	1976	1977
		Mean Square[a]							
Grazing Cycle (C)	3	254.41**	149.52**	90.50**	36.37**	5.29**	16.14**	798**	1333**
Stargrass (G)	2	6.77*	3.69	6.15	5.66	1.04	6.74**	432*	1029*
Stocking Rate (R)	2								
Linear	1	28.45*	1.21	20.35**	33.19	186.28**	107.72**	24232**	16776**
Quadratic	1	3.06	1.19	0.23	1.03	1.69	2.26	179	16
C * G	6	2.13	2.69	0.83	2.69	0.62	0.69	59	114
C * R	6								
Linear	3	4.39	0.01	4.34	6.87	2.07	3.68**	454*	510
Quadratic	3	2.61	1.06	0.88	0.76	0.59	0.61	49	177
G * R	4								
Linear	2	4.94	0.05	6.78*	2.50	0.66	3.58**	112	315
Quadratic	2	1.75	0.12	6.11	1.35	1.51	0.97	29	146
Residual	84	2.16	4.09	1.99	3.46	0.79	0.68	122	264

[a] * $P < .05$
** $P < .01$

Appendix Table 4. Analysis of variance for seasonal[a] dry matter yield and consumption on stargrass.

Source	df	Seasonal yield	Residue[b]	Consumption	% Utilization	Intake
		Mean Square[c]				
Year (Y)	1	42.44**	7.01**	14.96*	133.39**	2.42
Stargrass (G)	2	1.88	1.32	0.44	46.50*	0.36
Stocking rate (R)						
Linear	1	27.81*	29.17**	113.94**	1093.75**	21.38**
Quadratic	1	0.30	0.54	1.64	47.25*	0.01
Y * G	2	11.93	0.56	9.27	10.06	3.71
Y * R						
Linear	1	12.07	0.61	18.10*	32.86*	3.86
Quadratic	1	5.39	0.50	2.62	0.58	1.95
G * R	4					
Linear	2	3.14	0.23	5.06	17.82	1.77
Quadratic	2	0.76	0.01	0.08	3.68	0.44
Residual	4	2.65	0.30	1.85	3.14	0.91
Total	17					

[a]Two experimental years used as replication.

[b]Residue at the end of a grazing season.

[c]* P <.05
** P <.01

Appendix Table 5. Analysis of variance for forage quality measurements of stargrasses during 1976 and 1977.

		Forage on offer				Residue	
		IVOMD		CP		IVOMD	CP
Source	df	1976	1977	1976	1977	1976	1977
		Mean square[a]					
Grazing cycle (C)	3	28.4	200.1**	10.7**	44.4**	277.8**	0.2
Stargrass (G)	2	84.5**	255.3**	1.3	10.4	27.6*	1.4
Stocking rate (R)	2						
Linear	1	584.4**	235.3**	56.0**	14.7	91.3**	0.6
Quadratic	1	0.1	23.1	0.2	1.4	1.4	3.6*
C * G	6	17.1	11.1	4.1	2.5	2.3	2.1*
C * R	6						
Linear	3	28.2	5.5	1.6	10.6*	2.7	0.5
Quadratic	3	5.5	1.3	0.4	0.7	0.9	0.2
G * R	4						
Linear	2	2.2	9.5	1.9	7.2	1.1	0.5
Quadratic	2	3.3	20.9	2.5	0.5	2.8	0.7
Residual	84	17.5	10.8	2.5	3.9	8.4	0.7
Total	107						

[a] * P <.05
** P <.01

Appendix Table 6. Analysis of variance for forage evaluation parameters of five tropical grass entries at medium stocking rate during the grazing cycle in 1976.

		Forage production				
Source	df	Net	Available	Residue	Consumption	% Utilization
		Mean Square[a]				
Grazing cycle (C)	3	158.23**	81.13**	10.37**	36.18**	459**
Grass entry (G)	4	25.82**	78.09**	29.25**	12.16**	1800*
C & G	12	2.63	2.91	1.76	1.16	415**
Paddocks within G	16	0.54	2.33	2.04**	0.52	415**
Residual	48	3.03	2.22	0.51	1.91	157
Total	83					

		Forage quality				
		Forage on offer			Residue	
Source	df	IVOMD	CP	df	IVOMD	CP
		---Mean square[a]--			---Mean square[a]----	
Grazing cycle (C)	3	7.83	33.61**	3	139.68**	8.46**
Grass entry (G)	4	106.51**	1.78	4	10.53	2.66*
C & G	12	8.29	5.13	12	8.90	2.20*
Paddocks within G	16	21.39	1.45	16	4.30	0.67
Residual	48	15.07	3.23	43	14.83	0.86
Total	83			78		

[a] * $P<.05$
** $P<.01$

Appendix Table 7. Influence of stocking rate on cattle average daily gain, on stargrass pasture during 1976.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Mean
		Dates				
		6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	-Cattle/ha	kg/ha				
UF-5	7.5	0.56	0.52	0.62	0.15	0.46
	10.0	0.55	0.20	0.38	0.36	0.37
	15.0	0.11	0.28	0.14	0.44	0.24
UF-4	7.5	0.77	0.29	0.40	0.26	0.43
	10.0	0.52	0.31	0.46	0.07	0.34
	15.0	0.34	0.22	-0.10	-0.25	0.05
McCaleb	7.5	0.58	0.50	0.37	-0.02	0.36
	10.0	0.39	0.64	0.36	0.02	0.35
	15.0	0.19	0.27	0.02	0.24	0.18

Appendix Table 8. Influence of stocking rate on cattle average daily gain, on stargrass pasture during 1977.

Stargrass	Stocking rate	Grazing cycle 1	2	3	4	Mean
		Dates				
		6/7-7/19	7/19-8/30	8/30-10/11	10/11-11/22	
	-Cattle/ha-	kg/day				
UF-5	7.5	0.41	0.67	0.62	0.54	0.56
	10.0	0.47	0.59	0.32	0.24	0.41
	15.0	0.56	0.26	0.15	0.13	0.28
UF-4	7.5	0.65	0.70	0.44	0.27	0.52
	10.0	0.75	0.58	0.37	0.26	0.49
	15.0	0.62	0.30	-0.04	0.09	0.24
McCaleb	7.5	0.66	0.70	0.43	0.16	0.49
	10.0	0.80	0.40	0.14	0.08	0.36
	15.0	0.69	0.27	-0.02	0.07	0.25

Appendix Table 9. Analysis of variance[a] for average daily gain and gain/ha on stargrasses.

Source	Average daily gain						Gain/ha	
	UF-5		UF-4		McCaleb		All stargrasses	
	df	MS[b]	df	MS	df	MS	df	MS
Stocking rate (R)	2		2		2		2	
Linear	1	3.91**	1	7.92**	1	2.20**	1	42068.19
Quadratic	1	0.12	1	0.39+	1	0.001	1	20586.56
Residual	30	0.13	30	0.13	26	0.14	15	14917.80
Total	32		32		28		17	

[a]AOV for ADG conducted using all tester animals at the end of both experimental years and AOV for gain/ha conducted using the 18 seasonal beef product from both experimental years.

[b] + P <.10
 * P <.05
 ** P <.01

Appendix Table 10. Cumulative average liveweight (kg) of experimental heifers (testers) in 1976.

Grass entry	Stocking rate	Initial Wt.	Dates 7/13	8/24	10/5	11/16
	-Cattle/ha-	kg				
UF-5	7.5	253	276	298	324	331
	10.0	254	277	286	301	316
	15.0	253	257	269	275	294
UF-4	7.5	254	286	297	314	325
	10.0	253	274	288	307	310
	15.0	253	267	275	271	265
McCaleb	7.5	253	276	301	316	316
	10.0	253	269	296	311	312
	15.0	253	261	272	272	273
Digitgrass	10.0					
Replicate 1		253	278	302	303	300
Replicate 2		253	281	294	307	300
Bahiagrass	10.0					
Replicate 1		253	260	276	289	292
Replicate 2		253	279	284	292	277

Appendix Table 11. Cumulative average liveweight (kg) of experimental heifers (testers) in 1977.

Grass entry	Stocking rate	Initial Wt.	7/19	8/30	10/11	11/22
	-Cattle/ha-	kg				
	7.5	227	244	273	298	321
UF-5	10.0	228	248	273	287	297
	15.0	227	254	265	271	270
	7.5	227	254	284	302	313
UF-4	10.0	228	259	284	299	317
	15.0	228	254	266	265	269
	7.5	228	255	285	303	310
McCaleb	10.0	227	260	277	283	293
	15.0	232	261	272	271	282
Bahiagrass	10.0					
Replicate 1		228	259	266	274	281
Replicate 2		228	255	268	272	271

Appendix Table 12. Cattle grazing days at the various stocking rates in 1976.

Grass entry	Stocking rate	Grazing cycle 1	2	3	4	Total
		---Dates---				
		6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	-Cattle/ha	---Grazing days/ha---				
	7.5	315	315	315	315	1260
UF-5	10.0	420	420	420	420	1680
	15.0	630	630	630	630	2520
	7.5	315	315	315	315	1260
UF-4	10.0	420	420	420	420	1680
	15.0	630	630	630	525	2415
	7.5	315	315	315	315	1260
McCaleb	10.0	420	420	420	420	1680
	15.0	630	630	630	560	2450
Digitgrass	10.0					
Replicate 1		420	420	420	420	1680
Replicate 2		420	420	420	350	1610
Bahiagrass	10.0					
Replicate 1		420	420	420	420	1680
Replicate 2		420	420	420	397	1657

Appendix Table 13. Cattle grazing days at the various stocking rates in 1977.

Grass entry	Stocking rate	Grazing cycle 1	2	3	4	Total
		---Dates---				
		6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	-Cattle/ha	---Grazing days/ha---				
	7.5	315	315	315	315	1260
UF-5	10.0	420	420	420	420	1680
	15.0	630	630	630	455	2345
	7.5	315	315	315	315	1260
UF-4	10.0	420	420	420	397	1657
	15.0	630	630	630	350	2240
	7.5	315	315	315	315	1260
McCaleb	10.0	420	420	420	373	1633
	15.0	630	630	630	385	2275
Bahiagrass	10.0					
Replicate 1		420	420	420	397	1657
Replicate 2		420	420	420	373	1633

Appendix Table 14. Estimated grazing pressures on stargrass pastures at three stocking rates during 1976.

		Grazing cycle				
		1	2	3	4	
	Stocking	----Dates----				
Stargrass	rate	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	Mean
	-Cattle/ha	----kg DM/100 kg cattle BW/day----				
	7.5	12.30	13.83	8.25	7.80	10.55
UF-5	10.0	7.76	8.00	7.00	4.88	6.91
	15.0	5.64	6.06	4.74	2.40	4.71
	7.5	10.32	9.63	7.89	5.73	8.39
UF-4	10.0	8.08	8.60	6.60	4.80	7.02
	15.0	6.00	6.00	4.56	3.36	4.98
McCaleb	7.5	10.02	11.58	8.85	6.21	9.02
	10.0	7.96	9.24	6.28	4.96	7.11
	15.0	5.04	5.40	3.24	2.52	4.05

Appendix Table 15. Estimated grazing pressures on stargrass pastures at three stocking rates during 1977.

		Grazing cycle				
		1	2	3	4	
	Stocking	--------------------Dates--------------------				
Stargrass	rate	6/7-7/19	7/19-8/30	8/30-10/11	11/11-11/22	Mean
	-Cattle/ha	---------kg DM/100 kg cattle BW/day-------------				
UF-5	7.5	9.27	8.39	7.31	6.94	7.98
	10.0	7.88	5.91	5.61	4.49	5.97
	15.0	5.25	4.09	2.72	4.11	4.03
UF-4	7.5	10.31	9.55	9.26	7.12	9.06
	10.0	8.32	6.97	5.56	5.00	6.46
	15.0	5.60	4.48	3.91	3.62	4.40
McCaleb	7.5	10.98	10.41	8.68	5.89	8.99
	10.0	7.74	6.34	5.49	3.50	5.77
	15.0	4.74	4.04	2.82	3.15	3.69

Appendix Table 16. Estimated grazing pressures for five tropical grass entries at the medium stocking rate in 1976.

Grass entry	Grazing cycle 1	2	3	4	Mean
	--------------------Dates--------------------				
	6/1-7/13	7/13-8/24	8/24-10/5	10/5-11/16	
	-------kg total available DM/100 kg BW/day------------				
UF-5	7.76	8.00	7.00	4.88	6.91
UF-4	8.08	8.60	6.60	4.80	7.02
McCaleb	7.96	9.24	6.28	4.96	7.11
Digitgrass	7.42	6.90	4.44	1.82	5.15
Bahiagrass	4.68	4.64	2.22	1.36	3.23
	----------kg residue/100 kg BW/day----------------				
UF-5	3.59	3.28	2.79	3.03	3.57
UF-4	3.69	3.94	3.92	3.01	3.59
McCaleb	3.91	3.60	3.21	2.44	3.33
Digitgrass	3.68	2.32	1.64	0.60	2.06
Bahiagrass	1.75	1.55	0.74	0.29	1.08

Appendix Table 17. Analysis of variance for average daily gain adjusted for differences in grazing pressure of five tropical grass entries.

Source	df	Means square[a]
Grazing pressure (GP)	1	0.96**
Grass entry (G)	4	0.03
G * GP	4	.09
Residual	41	0.04
Total	50	

[a] * P <.10
** P <.01

Appendix Table 18. Analysis of variance for beef gain/ha from five tropical grass entries.

Source		df	Sum of squares	Mean square[a]
------------------------------Stargrasses-------------------------				
Grass (G)		2	45976.22	22988
Stocking rate (SR)		2		
	Linear	1	32224.01	32224
	Quadratic	1	19586.78	19587
G * SR		4		
	Linear	2	51769.63	25885
(Error a)	Quadratic	2	5017.48	2509
------------------------Digitgrass and Bahiagrass-----------------				
Grass (G)		1	8100	8100
Replicate (R)		1	1681	1681
(Error b) G * R		1	121	121
------------------All five tropical grass entries------------------				
Grass entry		4	72970	18243*
Pooled error (E_a + E_b)		3	5138.48	1713

[a]* $P < .05$

Appendix Table 19. Average total nonstructural carbohydrate in grass stubble during 1976 grazing season.

Grass entry	Stocking rate	Summer						Fall					
		Weeks after initial grazing											
		0	1	2[a]	3	4	5	0	1	2	3	4	4
		TNC, %											
UF-5	Low	7.92	8.60	5.89	5.46	7.16	7.58	6.38	5.38	4.72	4.50	3.94	5.56
	Med	6.87	6.07	4.49	5.36	6.66	6.48	7.12	5.69	4.90	3.89	4.44	5.43
	High	5.87	6.07	4.21	3.39	5.62	5.74	5.28	6.46	4.07	4.09	3.98	5.14
UF-4	Low	9.65	8.53	6.30	8.62	9.16	9.93	9.07	7.94	7.59	5.89	6.31	7.13
	Med	8.68	9.04	7.19	7.40	8.77	9.28	8.78	6.66	7.31	5.52	6.06	6.58
	High	9.08	8.22	5.36	8.28	8.03	8.33	7.48	6.76	5.46	4.13	4.71	5.69
McCaleb	Low	7.86	8.16	6.20	6.79	9.07	9.09	8.03	5.91	6.02	6.05	4.80	7.16
	Med	8.42	7.59	4.69	5.96	7.62	8.52	7.17	5.59	7.26	4.75	5.60	6.56
	High	7.99	6.49	4.51	5.31	7.35	5.88	5.37	5.90	5.70	4.40	5.06	5.77
Digitgrass	Med												
	Replicate 1	12.7	11.7	8.00	5.91	8.89	8.99	6.77	5.19	4.31	3.70	2.59	4.11
	Replicate 2	13.8	12.1	8.31	9.90	10.7	12.6	9.67	7.06	6.25	3.50	6.07	6.70
Bahiagrass	Med												
	Replicate 1	22.8	16.6	14.2	15.9	18.8	22.8	19.4	16.8	18.0	13.1	16.6	15.6
	Replicate 2	18.9	18.7	16.4	16.8	18.5	20.3	21.8	16.5	18.2	15.5	18.7	14.7

[a]Cattle grazing grasses from 0-2 week period, then removed

Appendix Table 20. Average total nonstructural carbohydrate in roots of grass during 1976 grazing season.

Grass entry	Stocking rate	Summer						Fall					
		Weeks after initial grazing											
		0	1	2[a]	3	4	5	0	1	2	3	4	5
		TNC,%											
UF-5	Low	10.1	9.88	5.19	6.58	7.39	9.41	9.66	9.43	7.52	7.70	7.50	10.3
	Med	8.38	9.26	7.49	5.38	7.34	9.10	8.40	9.70	7.59	6.28	7.07	8.42
	High	8.73	7.96	4.40	4.12	5.97	7.51	6.39	10.1	7.13	6.23	7.38	7.53
UF-4	Low	11.1	12.3	10.8	10.5	11.8	13.3	14.9	14.6	11.6	11.7	12.5	14.0
	Med	11.4	11.0	9.46	8.78	9.52	11.9	11.7	13.4	10.9	12.0	12.5	12.1
	High	9.80	10.7	7.49	9.96	10.8	12.1	13.0	13.5	9.79	8.60	9.56	10.6
McCaleb	Low	10.6	11.1	9.77	10.5	9.43	11.1	11.6	10.7	8.54	8.82	8.18	11.1
	Med	11.1	10.5	8.94	7.77	9.17	10.6	9.69	9.71	9.35	9.35	9.76	11.6
	High	8.65	9.42	7.01	6.80	6.99	9.74	8.89	9.48	7.52	7.02	9.29	10.3
Digitgrass	Med												
	Replicate 1	4.98	6.45	5.64	4.70	5.27	6.72	4.90	5.40	3.57	4.59	3.22	4.34
	Replicate 2	6.14	5.96	4.58	5.67	5.32	7.42	6.24	6.30	3.95	4.01	4.60	7.28
Bahiagrass	Med												
	Replicate 1	5.07	5.63	4.16	4.71	5.86	7.13	6.34	6.09	4.15	3.87	4.99	5.75
	Replicate 2	5.54	4.82	5.13	5.34	5.56	6.89	6.66	5.65	4.56	4.45	6.30	5.03

[a]Cattle grazing grasses from 0-2 week period, then removed.

Appendix Table 21. Analysis of variance for TNC in stargrass stubble and roots.

Source	df	UF-5	UF-4	McCaleb
		---------Mean square[a]---------		
Season (Summer, Fall) (S)	1	3.63	1.20	29.22**
Stocking rate (R)	2	52.43**	82.49**	89.42**
Weeks (cycle beginning from grazing) (W)				
Linear	1	56.04**	20.14**	2.08
Quadratic	1	229.76**	219.00**	225.65**
Plant Part (stubble, root) (P)	1	531.49**	1676.34**	927.64**
Subpastures (within R)	6	13.33**	12.03*	2.49
Replicates (within subpastures)	3	5.02	1.36	2.42
S * R	2	8.27	8.33	8.45
S * P	1	60.06**	256.27**	40.37**
R * P	2	2.11	8.33	2.91
W * R	2	0.67	2.34	0.42
W * P	1	0.25	3.66	0.17
W * S	1	0.00	81.43**	0.07
Residual	407	4.22	4.41	3.46
Total	431			

a
* P <.05
** P <.01

Appendix Table 22. Analysis of variance for TNC in digitgrass and bahiagrass stubble and roots.

Source	df	Digitgrass	Bahiagrass
		---Mean square[a]---	
Season (Summer, Fall) (S)	1	580.33	35.29
Replicate (Expt. Units) (R)	1	122.33**	7.26
Plant part (stubble, root) (P)	1	485.06**	10870.26**
Weeks (Cycle beginning from grazing) (W)			
Linear	1	65.89**	8.79
Quadratic	1	238.09**	304.06**
Subpastures (within expt. unit)	2	4.14	19.68
Replicate (within subpastures)	4	6.66	6.40
S * P	1	278.56**	27.73
S * W			
Linear	1	5.44	104.97**
Quadratic	1	2.04	32.47
Residual	273	5.74	11.86
Total	287		

[a]* P <.05
** P <.01

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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